ASPECTS OF HISTORY OF SCIENCE

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Introduction

The Asiatic Society, the oldest learned academic institution in modern India, has completed more than two centuries of its glorious existence for the advancement of knowledge, The Asiatic Society has been interested in History of Science in some form or other from its very inception. In one of his foundation address to the members of the Society, Sir William Jones broadly defined the objectives of the Society as the study of Man and Nature, "The bounds of its investigation will be the geographical limits of Asia", he said, "and within these limits its enquiries will be extended to whatever is performed by man or produced by nature." He placed equal emphasis on the study of history and other areas of humanities and various branches of Science and Technology.

Throughout the 19th century and till the end of the first half of the 20th, history of science formed a part of the oriental studies. During the 50's following a seminar on History of Science in South-East Asia held in Delhi under the joint auspices of the UNESCO and the Indian National Science Academy, a renewed interest in the study and research in history of science in India as a distinct branch of knowledge was generated. And this led eventually to the establishment of a National Commission for the Compilation of History of Science in India. A centre for History of Science was also established on January 15, 1985 at the Asiatic Society. The plans and programmes for which were drawn up by Professor Samarendra Nath Sen, the distinguished historian of Science with the help of his associate, Professor Santimay Chatterjee. One of the plans of the centre was to introduce a teaching course in the history of science leading to the M. Phil degree.

For reasons beyond its control, the teaching course could not be introduced for some time and it was only in 1994 the Society could introduce an one-year certificate course in history of Science for post graduate level students. This is the first time

that such a course has been introduced in an academic institution in India, though a proposal for introducing a course in history of science in Indian Universities was made to the University Grants Commission in 1957 by the Indian Society for History of Science, But unfortunately not tangible progress could be made.

The Asiatic Society is pleased to publish the Aspects of History of Science, a multi-authored monograph as an output of the workshop held in 2004 on History of Science and Society in the Indian Context. We strongly belief that this set of articles may be found useful to the students and scholars all over the world as a basis for further studies in the area of History, Science and Society in the Indian context. This monograph has been ably edited by the Joint Course Coordinators Professor Naresh Ch. Datta, Bilological Science Secretary and Professor Tulika sen, Anthropological Science Secretary of the Asiatic Society and assisted by Dr. Jagatpati Sarkar and other staff members of the Society. We thank them all. We also thank the experts, the teachers and scholars who have extended their wonderful support to run this workshop successfully.

Dilip Coomer Ghose
General Secretary

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Concepts of Ecology and Environmental Science—A Selective Historical Retrospect

N.C. DATTA*

About Beginnings

Who verily knows and who can here declare it,
Whence it was born and whence comes this creation ?
The Gods are later than this world's production,
Who then knows whence it first came into being ?

—The Ṛgveda

The real beginning of science, history and for that matter any branch of knowledge is always a mystery and obviously shrouded with uncertainties as well as conjectures. Long before the term science was coined, scientific ideas were there even in the prehistoric human society. In this context it may be mentioned that although Greek philosopher Aristotle (384-322 B.C.) is considered as the Father of Biology but the term Biology was not available at that time. It is now known that Lamarck and Treviranus, the two French biologists, coined the term in 1802.

Beginning of ecology

The genesis of ecology as a branch of knowledge is not decidedly known.

However, it is now presumed that even prehistoric man was very much aware of the benificient bond between man and

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nature. He has common knowledge, ecological in outlook, about plants and animals as well as some environmental factors like air, water, soil, temperature, light etc. This kind of knowledge of early man is now recognised as *Indigenous Technological Knowledge* (ITK) and also reckoned as the source of information forming the mother material of present day science. Such invaluable information may be found to exist in the pre-Greek Mesopotamian, Egyptian, Chinese and Indian civilisations. In recent years a search for such information is going on which is expected to unveil the wisdom of the early man. The western historians of science consider Theophrastus (372-287 B.C.), a Greek Botanist, Philosopher and a student of Aristotle, as the first ecologist. But it is rather really difficult to substantiate this claim as because long before the Greeks the ancient Indian people during Vedic period were very much conscious of the relationships among man, plants, animals and nonliving components of environment. The early Indian philosophy proclaims that man is a part of Nature and there is harmony between Man and Nature. It is indeed very remarkable to note that according to Vedic concept man cannot be placed at the central point of cosmos and also cannot be considered as a dominant factor over other components of environment. Each and every organism has got intrinsic value and also has the right to exist irrespective of human use. This concept is known as *biocentrism.* All components of environment have got some part to play for the existence and survival of man and healthy environment is indispensable for well-being of mankind.

The Vedic people chanted the following hymn :

"May the winds blow like honey, unpolluted.
May the rivers flow like honey, unpolluted.
May the particles of dust bear honey.
May the upper atmosphere of heaven,
We call our father, bear honey.
May our plants and trees bear honey.
May the sun, the source of light, bear honey.
May our animals, the cows and others, bear honey in themselves."

The deeper meaning of this prayer is the quest for congenial environment. Be it understood, that honey symbolises pristine purity, bliss and abundance. Many such prayers may be found in ancient Indian literature which pronounce the indispensability

of environment in its totality. Keeping the above narration in view Datta (1990) stated that ecology was thus born without a COGNOMEN and a DEFINITION although the idea of ecology was in existence.

However, contrary to the Indian view of ecology, the Judaic-Christian Philosophy or Western Philosophy considers man as the master of all living things and not merely a passive or subservient component of Nature. It also emphasizes that Nature existed for man to be used and exploited by him for his own purpose. This philosophy is known as *anthropocentrism*. The following passage from the book of Genesis (1:28) explicitly emphasizes the anthropocentric attitude of the Judaic-Christian Philosophy which has largely been followed by the western countries.

> "Be fruitful and multiply, and fill the earth and subdue it; and have dominion over the fish of the sea and over the birds of the air and over every living thing that moves upon the earth."

White (1967) in his article entitled, "The historical roots of our ecological crisis" categorically stated, "We shall continue to have a worsening ecological crisis until we reject the Christian axiom that Nature has no reason for existence save to serve man."

Of course, Southwick (1976) contested the contention of White by stating that long before the formulation of Judaic-Christion Philosophy, ecological damage had occurred in the countries where Judaic Christian Philosophy is not followed. However, it is also no denying the fact that rapacious exploitation of Nature by man will upset the homeostasis of environment and will cause irreversible changes in the structure and function of ecosystem.

Keeping aside the philosophical perspectives, let me now try to trace the genesis and development of ecology as a scientific discourse. Since broadly speaking ecology is concerned with the study of environment, it will be worthwhile to define environment at the outset. Environment (Fr. *Environner : environ*-around, *virer,* to turn around) according to common man's perception means just surroundings—a non-technical word which does not communicate the depth and dimension of the term in a technical sense. From ecological standpoint environment essentially comprises two discrete and distinct components : **(1) Habitat diversity**—(the nonliving or abiotic

part) and **(2) Biodiversity** (the living or biotic part). In reality these two components constitute the corpus of ecology.

Definition of ecology

There is uncertainty regarding the first coinage of the term ecology. Although German Biologist Ernst Haeckel (1834-1919) is very often credited to have first coined the term ecology but following Eggerton (1977), Kormondy (2000) stated that Hanns Reiter (1865) first combined the Greek words *oikos* meaning "house" and *logos* meaning "the study of" to constitute the term ecology. A year later in 1866 Haeckel also used the term ecology and in 1870 he precisely defined ecology, which is as follows :

> "By ecology we mean the body of knowledge concerning the economy of nature—the investigation of the total relations of the animal both to its inorganic and to its organic environment, including above all, its friendly and inimical relation with those animals and plants with which it comes directly or indirectly into contact—in a word, ecology is the study of all the complex interrelations referred to by Darwin as the conditions of the struggle for existence."

With the above definition, the discipline of ecology could get a definite impetus to develop as a distinct branch of biology. Of course, there are quite a number of definitions of ecology. Charles Elton (1927), the British ecologist, defined ecology as "scientific natural history" concerned with the "sociology and economics of animals". Odum (1971) defined ecology as the "study of the structure and function of nature". The definition of ecology provided by Southwick (1976) is straight forward and concrete. In his opinion, "Ecology is the scientific study of the relationships of living organisms with each other and with their environments". In this context some more terms tangential to ecology may be mentioned. French Zoologist St. Hilaire in the last half of the 19th century introduced the term **ethology** for the study of the relations of the organisms within the family and society in the aggregate and in the community". St. George Jackson Mivart, an English naturalist, at about the same time used the term **hexicology** to depict the study of the relations existing between the organisms and their environment and also the relations among the organisms themselves. Sociology is also akin to ecology which according to Kendeigh (1975) encompasses

the ecology and ethology of mankind. However, the term hexicology is now obsolete and both ethology and sociology are now developed as well defined and distinct disciplines.

Emergence of modern ecology

All the definitions of ecology mentioned above basically pertain to classical ecology as we may christen it. By classical ecology we essentially mean "the study of the relationships of living organisms with each other and with their environments". But this definition fails to reflect the human dimension in ecology, as if man is not a part of Nature but rather apart from it. During last half century or so, there has been a paradigm shift in the content and concept of ecology. Man and his society with all its attributes and role have now become indispensable elements in ecological thinking and application. Ecology has now become a common vocabulary for the politicians, planners, policy makers, philosophers, futurologists and even industrialists. It has now gained the rank of a synthetic science, multidisciplinary in nature and boundless in its concern due to immense input from all branches of knowledge. Datta (1990) stated, "Although ecology is biological in its marrow but it has now become a **social science, a basic component of liberal education** from commoner to elite" and "he also **defined ecology as a branch of science or rather of discipline of human knowledge dealing with the strategies of survival of man and biosphere in space and time.**" Regarding the imperativeness of ecology in human life, the following worth mentioning passage from Southwick (1976) may be quoted : "Rarely has an academic subject become such a major issue in the public consciousness as ecology in the late 1960s and early 1970s. Within a few years, ecology progressed from a rather quiet and obscure branch of biology to a subject of national and international concern. Education, business, politics, law, agriculture, engineering, medicine, public health, and even international affairs were all affected by the sudden upsurge of ecological and environmental concern." It is explicit from the above narration that ecology is a keystone subject for mankind and should be given due attention and importance for his well-being.

Environmental science and its genesis

With the advancement of knowledge, new terms are innovated to deal with the new concepts. Biotechnology, Bioinformatics, Information technology and Environmental Science are few such terms. After the UN conference on the Human Environment in 1972 at Stockholm, the term Environmental Science has become very popular and widespread. In India and in many other countries, Environmental Science has become a compulsory subject at the degree level which obviously indicates its importance. **But what is Environmental Science and how it differs from Ecology?** These questions need clarification. Ecology is an age old term. Ecology or classical ecology *per se* is considered mostly as an academic discipline meant for deciphering the relationships between organisms and environment. Although both ecology and environmental science have many aspects in common and both are concerned with the study of environment in general yet, there are some differences in their concept and practice. It seems that the scope of ecology is somewhat narrower than that of Environmental Science. The key points considered in Environmental Science are the maintenance of the environmental quality for ensuring good human health, conservation of natural resources for sustainable utilisation and development so that "people can build a future that is more prosperous, more just, and more secure" as emphasized by the World Commission on Environment and Development in their report entitled, "Our Common Future" (WCED, 1987). The said report discusses the critical issues like deforestation, poverty, climate change, loss of biodiversity, the debt crisis, and depletion of the ozone layer in the stratosphere. All these are the main concern of the Environmental Science. It seems logical to assume that *Environmental Science is not a new species of Science and its roots lie deep in Ecology.* In brief, it may be stated that **Environmental Science integrates many branches of science with Sociology, Economics, Education, Politics, and Philosophy exhibiting a holistic principle in the domain of environment.**

Chronology of the events regarding global awareness about environment during last half century

In many national and international conclaves, environmental issues have become an almost obligatory agenda of vibrant socio-political encounter. Colossal conflict of interests between the developed and developing countries with regard to global warming, emission of green house gases, ozone layer depletion, loss of biodiversity, acid rain, overuse of plastic and other synthetic material, discharge of hazardous wastes is in constant succession. Furnished below a number of such conventions of last half century in chronological order (Datta, 2003). Obviously, these events explicitly reflect our anxiety and concern about environment.

1948 UN Charter International Union for the Protection of Nature (IUPN) established.

1956 Man's role in changing the face of the Earth. An international symposium held at Chicago, U.S.A.

1957 The IUPN becomes the International Union for the Conservation of Nature and Natural Resources (IUCN).

1958 Law of the Sea. The first UN Conference on the law of the Sea (UNCLOS) approves the draft convention.

1959 Antarctic Treaty signed.

1961 Establishment of World Wildlife Fund (Worldwide Fund for Nature).

1962 'Silent Spring' by Rachel Carson published.

1963 International Council of Scientific Unions (ICSU) established the International Biological Program (IBP).

1966 IUCN Red Data Book first published.

1968 UNESCO 'Biosphere' conference held.

1969 Friends of the Earth (FOE) founded.

1970 The US National Environmental Policy Act (NEPA) requires preparation of Environment Impact Assessment (EIA).

1971 Man and the Biosphere Program (MAB) of UNESCO launched. Greenpeace International founded.

1972 UN Stockholm Conference on the Human Environment. Concept of a Global Environmental

Monitoring System (GEMS) endorsed by the Stockholm Conference. United Nations Environmental Program (UNEP) established. 'Blueprint for Survival' sponsored by the Journal Ecologist. 'Limits to Growth' published (Club of Rome Report).

1974 UNEP Regional Seas Program initiated.

1975 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

1976 The Scientific Committee on Problems of Environment (SCOPE) reports to the International Council of Scientific Unions (ICSU) on global trends in the Biosphere most urgently requiring international and interdisciplinary scientific effort.

1979 UN Conference on desertification, World Climate Conference Organized by the World Meteorological Organization recognizes the 'Greenhouse effect'.

1980 World Conservation Strategy (IUCN) launched, IUCN Conservation Monitoring Centre (now the World Conservation Centre) established. The global 2000 report forwarded to the US President Carter.

1982 UN Nairobi Conference, ten years after the Stockholm Conference. World Charter for Nature adopted by UN. The World Environment 1972-1982 published. The World Commission on Environment and Development (WCED) established.

1984 The Resourceful Earth, A response to Gobal 2000 is published.

1985 Vienna Convention for the protection of the ozone layer.

1987 'Our Common Future' published (WCED), Montreal Protocol on substances that deplete the ozone layer.

1988 Oslo Conference on Sustainable Development to get away from the tyranny of the immediate.

1989 The 'Green Summit' in Paris of G7 (Canada, USA, France, Italy, Japan, UK and West Germany). Urgent need to safeguard the environment is emphasized. IUCN published 'From Strategy to Action' a response to 'Our Common Future'. Saving the Ozone Conference in London (UK and UNEP). Basle Treaty on International Transport and

Disposal of Hazardous Wastes. Non-Aligned Movement (NAM) conference at Belgrade. Proposal for Planet Protection Fund. Langkawi (Kualalampur) declaration on environment. Hague declaration on ozone depletion and global warming.

1990 Tokyo Conference—a youth perspective on Sustainable Development. The role of economics and education limelighted.

1992 Rio Conference (UNCED), Major environmental issues discussed are : Deforestation, Biodiversity loss, Climate change, Marine and Coastal Zone, Law of the Atmosphere Ozone layer depletion and Agenda 21. The Agenda 21 is intended to set an international programme of action for achieving sustainable development in the 21st century.

1997 Kyoto Conference on global warming.

2002 World Summit on Sustainable Development (26th August to 4th September, 2002) Johannesburg, South Africa.

Box 1 : Five Agreements of UNCED, 1992
(Earth Summit at Rio, Brazil)

1. The framework Convention on Climate Change
2. The Convention on Biological Diversity
3. The Rio Declaration
4. The Forest Principle
5. Agenda 21

Box 2 : World Conservation Strategy, 1980
(IUCN, WWF, UNEP)

1. Maintenance of essential ecological processes
2. Preservation of genetic diversity
3. Sustainable utilization of species and ecosystems.

Epilogue : It is now understood that man is totally dependent on environment not only for his survival but also for his continuance. In order to maintain the sustainability of clean environment I suggested the following set of **ten golden rules**

which has already been christened as **New "Ten Commandments"** (Datta, 1990). Ten Commandments are the ten laws which were given by God to Moses on Mt. Sinai :

- Man's place and role in nature should be re-examined.
- Man should refrain from making large scale transformation of environment without proper Environmental Impact Analysis.
- Man as a part of Earth Watch Programme should ensure that the fate of the **"global commons"** does not end in the **"tragedy of the commons"**.
- A balance between population growth and resource utilization should be established.
- The gap between the rich and the poor, between the developed and developing, as well as between the developed and underdeveloped countries should be narrowed.
- Equitable distribution of resources to all for rightful use should be allowed and needful conservation of vital resources should be practised.
- Essential ecological processes should be allowed to continue in time and space without any impediment.
- Abuse and misuse of resources should be avoided and wastes should be recycled as far as practicable.
- Man will have to develop a profound respect for Nature.
- Man should remain altruistic.

Box 3 : Causes of Crisis in Civilisation

Obstinate anthropocentric attitude, ruthless egocentric behaviour and all-out oligarchic temperament of man are the root causes of present day ecological crises.

Datta (2003)

In fine, it may be asserted that **a new philosophy of life with respect to preservation of environmental quality is to be evolved** so that man and biosphere is not subjected to crisis of existence.

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Biotechnology

DHURUBAJYOTI CHATTOPADHYAY*

Biotechnology seems to be leading a sudden new biological revolution. It has brought us to the brink of a world of "engineered" products that are based on the natural methods rather than on chemical and industrial processes. The term "biotechnology" was coined in 1919 by Karl Ereky, an Hungarian engineer. At that time, the term meant all the lines of work by which products are produced from raw materials with the aid of living organisms. Ereky envisioned a biochemical age similar to the stone and iron ages. In its purest from, the term "biotechnology" refers to the use of living organisms or their products to modify human health and environment. Prehistoric biotechnologists did this as they used yeast cells to raise bread dough and to ferment alcoholic beverages. They used bacterial cells to make cheese and yogurt and bread strong, productive animals to make even stronger and more productive offspring. Throughout human history, we have learned a great deal about the different organisms that our ancestors used so effectively. The marked increase in our understanding of these organisms and their cell products gains us the ability to control the many functions of various cells and organisms. Using the techniques of genetic engineering and recombinant DNA technology, we can now actually combine genetic elements of two or more living cells. Functioning lengths of DNA can be taken from one organism and placed into the cells of another organism. As a result, for example, we can force bacterial cells to produce human proteins. Cows can produce more milk for the same amount of feed. And we can synthesize therapeutic molecules that have never before existed. New biotechnological techniques have permitted scientists to manipulate genetic material to improve his way of life for millennia.

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Biotechnology at the beginning of the twentieth century began to bring industry and agriculture together. During World War I, fermentation processes were developed that produced acetone from starch and paint solvents for the rapidly growing automobile industry. The chemist, C. Weizmann showed that propanone could be produced by the bacterium *Clostridium acetobutylicum*. The advent of World War II brought the manufacture of Penicillin. These years were dominated by work with microorganisms in production of antibiotics and developing new fermentation processes. Biotechnology is currently being used in many areas including agriculture, bioremediation, food processing, and energy production. DNA fingerprinting is becoming a common practice in forensics. Production of insulin and other medicines *is* accomplished through cloning of desired genes. Immunoassays are used not only in medicine for drug level and pregnancy testing, but also farmers to aid in detection of pesticides, herbicides, and toxin in crops and in animal products. These assays also provide rapid field *tests* for industrial chemicals in ground water, sediment, and soil. In agriculture, genetic engineering is being used to produce plants that are resistant to insects, weeds, and plant diseases. Today's biotechnology has its "roots" in chemistry, physics and biology. The explosion in techniques has revolted in three major branches of biotechnology: genetic engineering, diagnostic techniques and cell / tissue engineering. Biotechnologists now 'programme' the bacteria to make many other types of drugs that the organisms could not otherwise produce. Human insulin, for the treatment of diabetes, human growth hormone to treat children who would otherwise reach abnormally short stature, interferon for the treatment of certain types of cancers, erythropoietin which is given to patients undergoing dialysis for kidney problem — all these products are now being prepared from either microbes, plants or animal cells by using biotechnological methods. Biotechnology is beginning to revolutionize vaccine production. Genetically engineered vaccine is already widely used against hepatitis B. Another rapidly developing area of biotechnology is the use of microbes to break down pollutants in the environment. Microbes can also be used to leach metals such as iron, zinc and uranium out of inaccessible and low-grade ores. A tenth of the copper produced annually in the United State is recovered in this way. "Microbial mining" is increasing its importance as high-

grade and easily accessible mineral deposits are depleted. Ease of production is the motive behind the current emergence of biotechnology using animals and plants. To develop crops and other plants with advantages such as resistance to pests and drought and improved palatability and nutrient content are the challenges to the Agricultural and Plant Biotechnologists. Animal biotechnology has emerged as a powerful tool after the successful cloning of Dolly. The human gene for alpha- 1 antitrypsin, which is used to treat the chronic lung conditions emphysema, has been incorporated into the DNA of sheep in such a way that it programmes the animals to produce the alpha-I antitrypsin in their milk. The same method has been adapted to direct sheep to produce blood clotting factor IX, which is required by people suffering from hemophilia. Recently the scientists are also considering to use the Deoxyribonucleic acid (DNA) molecules for computing purpose. DNA molecules can store far more information than any existing computer memory chip. It has been estimated that a gram of dried DNA can hold as much information as a trillion Compact Discs. The knowledge of surface chemistry could be used to make the biggest nonconventional computers. Conventional digital computers represent information as a series of electrical impulse using ones and zeros. DNA computing depends on information as a pattern of molecules arranged on a DNA strand.

The development of biotechnology also raises lot of concerns. One concern is the alleged unpredictability of releasing genetically altered organisms in the environment. The official committees that regulate biotechnology in most countries assess the risks very carefully before giving permission for particular experiments to proceed. Other anxieties centered on the impact of modem biotechnology particularly on the socio-economic condition. It is important to give a clear perception of the new biotechnological concepts to the public to allay their fears.

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Potters, Painters, Seal and Bead Makers : Applications of Chemistry at Harappa

NUPUR DASGUPTA*

We observe the applications of scientific processes in practical works of life very early in the pre-Harappan and Mature Harappan society. We are indebted to scientists of the modern days for aiding us in discerning the actual ways in which the Harappan artisans and technicians had put to use their acquired knowledge of technology and science. A number of researched works, and reports of scientific analyses have been contributed by scholars on the subject of employment of scientific processes by pre-Harappan and Harappan people. Here we are making an attempt to highlight a specific process of scientific application, the science of chemistry, at it rudiments, which is observed as put to use by Harappan artisans in different segments of craft production - as old as more than five thousand years ago.

The paper discusses certain points regarding the residual evidences found at the site of Harappa, in the course of earlier and recent excavations at the site. The evidence points to high temperature activity in certain sections of the site. The artefact - based evidence also enables us to distinguish the particular crafts that required such high temperature processing. While identifying these crafts and their residual signs, we get ample clue to the craft activity at the site, which leads to the idea that the economy at Harappa could have been focused on specific craft activities and long distance trade. The recent excavations at Harappa also testify to this nature of the site.

We are now left with an impression of specialized craft production and an efficient handling of pyrotechnology by the artisans at Harappa in which a working knowledge of chemistry had had a big role. What would these entail for the craft-production lay - out or the knowledge base? Whether the artisans

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concerned were aware of the principles of the technical operations they were involved with or whether it was a traditional, need – based, repetitive operation – is a question that needs to be resolved. Moreover, what effect could these high temperature operations have had on the ecology and material environment of the site and region around are some questions raised, which can only be answered through more extensive explorations in the vicinity, collection of palaeobotanical evidences and constructing possible mechanisms of interconnectivity between Harappa and beyond to zones of primary resources.

Recent researchers have rightly identified Harappa of the protohistory times as a site focused on craft production and trade. As such we are interested in the particular crafts in which Harappan artisans seemed to have specialized and the technology and resource input. The most notable finds both in the earlier excavations conducted by M.S.Vats [1] and the recent one by Meadow and Kenoyer[2], are the steatite seals with raised script, faience objects, beads and copper objects. All of these require high temperature processing. Therefore, this paper begins with the attempt at finding the evidences for high temperature firing, and co-relating them to possible crafts. Besides the paper also attempts to draw attention for wider inferences regarding the factors associated with crafts productions. We begin with the evidences from the recent tests done by Heather M. - L. Miller.

Miller[3] conducted large-scale area survey, walking at 0.5 to 1 m. intervals, flagging artifacts to be tabulated. The results from this large -scale survey were used to select specific areas for more intensive surface survey and geo-magnetic testing for the second phase of her work. She conducted the survey and tests to locate the remains from ancient high-temperature manufacturing to determine the spaces where high temperature activities took place within the city of Harappa. She has described several types of high-temperature manufacturing debris found at the site which appear to be indicators of the firing stages from a number of craft industries, one of them being metal processing. We are interested in her findings so far as the high-temperature manufacturing processes are involved. The main aim in this paper is to locate and distinguish the craft techniques, which required high-temperature firing and the artisan

efficiency in managing such activity. We are also interested in distinguishing the tempering elements used in each case of specific craft production as well as the degraissant used in the making of both metallic and non-metallic objects.

Miller's initial study and reporting indicate initial evidences from Harappa regarding pyrotechnical processing. The first half of this paper therefore deals with Miller's findings and the hypothesis about the possible crafts associated with these findings. The second half deals exclusively with the evidences found at Harappa for metal processing, the conclusions thereof and the possibilities arising out of such conclusions.

The Indus civilization crafts people produced an impressive variety of objects made by the transformation of materials at high temperatures. Such materials include non-ferrous metals, fired steatite and talc, and a range of ceramics, including terracotta, a very high-fired stoneware, siliceous paste or 'faience', and a steatite paste.

The firing stages of these high-temperature industries leave burnt and vitrified by-products or slag of many types. Miller uses the term slag in the wide sense of burnt residue and not exclusively the residue of metal processing. This includes all silicate based materials affected by fire and heat,; partly molten or vitrified material as well as glassy and crystalline slag proper. The location of such by-products at an archaeological site is one of the best indicators of high-temperature manufacturing.

Now, as to the exact findings of Miller in this initial stage, she located vitrified kiln wall fragments and clay drips, straw tempered 'dishes' with white coating, manufacturing debris containing bone fragments and copper metal processing debris.

The surface of Harappa is covered with vitrified clay fragments. Pracchia and Vidale[4] note that individual drips are particularly indicative of melted-down covered kilns. We shall observe this in more details when we take up the evidence from the older excavation conducted by Vats at the site. Miller's study has brought out another interesting point that, the Indus kilns and hearths at Harappa typically have straw-tempered clay coatings on their surfaces. Drips and straw tempered coating fragments therefore can safely be assumed to indicate heating structures in which high temperature crafts processing were being conducted especially where the oven was over-fired. Several concentrations of such slag have been found at Harappa.

However, as Miller herself admits, specific craft processing have not yet been properly identified. Yet, with the evidence in hand we may make certain assumptions based on the findings of actual products of such craft processing to make a surmise regarding craft specialization at Harappa and the pyrotechnology involved in such processing.

To begin with at Harappa we come across a significant amount of micro-beads made of steatite paste, which was made hard by heating. These beads are a distinct feature of Harappan culture. So are the beads made of 'faience', which is obtained by amalgamating lime with quartz at high temperature.[5] The etched carnelian beads are typical of Harappan culture. The etchings were put on by first immersing the designed beads in a plant derived alkaline substance and then heating them for the absorption of the alkali by stone. Let us talk about the microbeads of steatite for the technology in this case is remarkable, and the work required pyrotechnology for the completion of the product. The tiny beads are of immense value to the students of Harappan Technology. The chemical test [6] shows that the bead material is 60 percent silica, 30 percent magnesia, 6 percent alumina, less than two percent lime and less than 1 percent iron oxide. The test also shows that they were not made from pure talc, which is a hydrated silicate of magnesium. The presence of alumina suggests presence of kaolinite, which is a hydrated silicate of aluminium. It is one of the pure forms of clay, a material, which is seen to occur naturally with the metamorphosed ultra - basic rocks, and is known as talcose steatite. The X-ray diffraction analysis carried out by K. T. M. Hegde, R.V. Karanth and S.P. Sychanthavong revealed the presence of silica in the form of cristobalite and anhydrous magnesium silicate in the form of enstatite. This is achieved by heating at a level above 850° centigrade, where talc diecomposes giving off its water of crystallization and forms cristobalite and enstatite becomes hard in the process. The team found out that when steatite is heated at 900° centigrade for two hours the hardness improves. The hardness was also required for the smooth drilling of these microbeads, measuring from 1 to 3 millimeter in length and 1 millimeter in external diameter. The hardness of beads clearly tested to have been structured at high temperature (6 to 7 on Moh's scale)[7].

Stoneware bangles are nothing but terracotta bangles fired

at a high temperature. The next craft, which required high temperature processing, is seal making. Harappan seals were intaglios made of steatite. These were first cut to a shape with a minute saw. The boss was then shaped with a knife and bored from either end. The carving of the motif was done with a minute burin and at some stage the seal was banked to whiten and harden its surface. An alkali was probably applied to the surface before firing to assist in the whitening and to glaze it[8]. If we go by Sana Ullah's tests we find this smooth glassy looking substance, covering the seals to contain :

Silica	61.20	percent.
Oxides of aluminium and iron	2.4	percent.
Lime		
Magnesia	34.6	percent.

The surface of the substance is steatite or talc. The body and the coating of the seals are of the same material. But, as P. Ray has pointed out the coating might have been applied on the body and then fired to obtain the glaze[9].

Sana Ullah carried out the analysis of further vitrified pastes, which might have been used for glazing seals. As reported it resembles glass in some respects :

Silica	88.12	percent
Aluminium oxide	3.12	"
Ferric oxide	1.82	"
Lime	1.26	"
Alkalies	5.04	"
Cupric oxide	0.46	"

The mixture was probably fired at about 1200° C[10]. These materials are found in slab form. A little soda might have been used with the powder made from these slabs to serve as flux. Interestingly enough it has been suggested that since it is extremely difficult to make the powder adhere to steatite bodies, "the powder might have been mixed with certain oils, which would volatize at high temperatures leaving no trace behind. The other process would be heat the slabs to a semi-fluid state and then apply to the body of the material to be glazed, followed by prolonged heating of the object in order to make the glaze flow freely over it."[11]. However, there is no evidence of over-firing. So a controlled firing in closed kilns is suggested.

Sana Ullah also assumed that a second firing of the steatite seals might have been done. Glazed pottery making is also evident from Harappa, which also required high temperature firing.

Meanwhile the latest reports from Harappan excavation conducted by Meadow and Kenoyer[12] are available. This report highlights the craft activity signs at the site. Excavation trenches in their mound ET, south-western slope reveal "that a bazaar like area with numerous workshops was located on Mound ET inside the city wall but near the gateway. What is more significant is the close association in a limited area of many different crafts that produced items for elite consumption; shell working, agate bead making, steatite bead making, faience manufacture, gold working, bone and ivory working, wood working and chert weight manufacture." Of these, high temperature processing is required for faience and bead making. Moreover, the trench 9 of the Mound ET has produced evidence for workshops and hearths producing pottery and some bead making (9). The trench 10W of the Mound E has produced evidence of concentration of numerous steatite, terracotta and faience inscribed tablets or seals (10). Vats had found a similar concentration of incised steatite tablets in Mound F. As Meadow and Kenoyer have pointed out the evidences at Harappa indicate the nature of the site to have been focused on craft activity. "...the ancient Harappans were technologists of the small and miniature." [13]

The initial survey of Miller has revealed the presence of some straw tempered dishes with traces of white coating. The function of these dishes is not yet clear. But it is true that these were exposed to a very high temperature. The white coating is a fine powder of steatite, which has been heated to a temperature above 800° C. The tests carried out at the *Laboratoire de recherche des Musees de France* indicate the possibility of these dishes having been used for insulating their contents from heat fluctuations. The use of steatite as refractory coating is yet another aspect of Harappan pyrotechnology.[14] The manufacturing debris containing bone fragments have been found by Miller[15]. This slag is porous or frothy, lightweight and light coloured. Other associated artefacts include hand-formed dishes with inner surface covered with tiny bone fragments, bone-tempered flat tiles with glossy surfaces. The association of these objects are

probably related to not only siliceous pastes or faience production but also steatite or talc bead production, already discussed and found to be popular crafts at Harappa, especially.

Lastly we deal with the findings of Miller[16] regarding evidences for copper metal processing. Copper processing slag was found scattered in few quantity over Vats' area J, and the southern side of Mound AB (citadel mound), and the majority of slag, more than two hundred fragments, were found on the south side of Mound E. According to Miller this slag come from one or more melting sites. However, initial geomagnetic results show no evidence for any remaining kiln beneath this area. Miller admits that initial results may not be conclusive. Remains of straw tempered clay fragments from kiln walls and crucible fragments have been found. But all the crucibles were found to have been heated from top, probably using a tuyere, indicating melting of copper. However, true metallurgical slag is scanty and no ore fragments have been found, indicating the possibility of copper melting at Harappa on this Mound especially, and not smelting.

Let us now go back to some of Vats' evidence for pyrotechnology and copper metal processing at Harappa. The several pieces and bits of the slag found at Harappa are in general contextually associated with urns [17] and not with metal working or furnace remains. What this means is another of puzzles about Harappa. The evidence for secondary manufacture is as follows: a shallow earthenware crucible, oval at the base and with straight sides in mound AB, sq. P[18]; fragmentary earthenware crucible found in Mound F, near a furnace "whose contents show that it was used for melting bronze." [19]; and the presence of unfinished and un-worked copper objects, especially those found from jar 277 reported in Vats' excavation[20], and numerous pieces of copper, weighing about 2 lbs found in Mound AB, sq. 24. The copper objects at Harappa found by Vats were found to be mainly rich in arsenic content. A piece of yellow arsenic was found in Mound F[21] and a lump of lollingite was found in jar 277 in Mound F[22]. About the last A.K. Biswas also agrees that arsenic may have been extracted from lollingite and used to harden the cutting edges of tools instead of tin alloy [23]. All these involved firing at considerable temperature. Vats also considered the possibility of metalworking being done in a number of furnaces, which were discovered in Mound F. These

are found to have been of three types. There is a pottery jar furnace, three-fourths of which is embedded in the ground showing contact with fire. Two cylindrical pits dug in the ground have been found with evidence of fairly intense firing. One of them, furnace Fa, is 3 ft. 4 in. in diameter, with a depth of 3ft. 8ins. There is evidence of a slanting flute, which served as an air channel for the furnace. A part of the vaulted roof of the furnace was also found lying inside it, and there were flues in this vaulted roof probably as outlets for smoke or as gaps to be covered when the heat had to be conserved. Thirdly there are thirteen pear-shaped pits dug in the ground, often with a column[24]. According to Vats these were used for metal crafting. A. K. Biswas is of the opinion that the jar furnace, Fb was used for pottery firing. But he also points out that this type of furnace with charcoal as fuel is still used by gold and silversmiths in India[25]. About the cylindrical shaped furnace Fm Biswas notes, "It is paved and lined exclusively with courses of brick-on-edge. The walls are mud plastered and along with ashes a lot of highly vitrified slag was found in it. This indicates fairly long intense firing, but no object was recovered in or around it."[26]. About the remaining thirteen furnaces Biswas observes from the report of Vats that the eight of them, which were brick-lined, were also plastered with mud mixed with a quantity of sand in order to resist fusibility. In many of them there is a small rectangular pillar or wall set at the back and an air passage for circulation of heat between itself and the back wall. Intense vitrification has led to the run down or caving in of the brick wall as already noted by Miller in some cases mentioned above and pointed out by Pracchia and Vidale[27]. The repeated use of these furnaces for firing objects is clear from the fact that there is evidence of repeated re - plastering of the furnaces with sand and mud when the original plaster had converted into slag due to intense heating. Biswas also agrees with Vats that these furnaces were used for something other than making pottery, since pottery does not require the kind of intense heating evident here as well as the fact that the furnaces are too small for pottery firing. Biswas points out, "More probably these were designed for the casting of metal objects. There is abundant evidence to show that such metal objects were manufactured locally."[28] That these furnaces could have been also used for firing faience objects, stone ware bangles, glazing steatite seals and small vessels or

putting on bands of coloured frit on faience vases or for etching beads have also been suggested by him quite rightly. In fact Miller's findings support his suggestions. About copper processing, though evidence point to local casting and melting of copper at Harappa, the smelting of copper is not well attested locally. Miller gives a reserved opinion, " To date, there are only three or four small fragments of true metallurgical slag and no ore fragments, reinforcing the conclusion that this was a melting, not smelting site."[29] Most of the remains with copper enrichment and prills are amorphous fragments of vitrified clay. There are also straw tempered clay fragments from kiln walls, as well as a number of straw tempered clay crucible fragments, some with sand-sized quartz particles on their inner surfaces.

To clarify the matter of the use of pyrotechnlogy at Harappa we should also note where and how firing of pottery was conducted. It seems from the initial report from the recent works at Harappa conducted by Meadows, that the two new tear-drop or pear shaped kilns found leaves no doubt that these were used for ceramic production[30]. As to firing temperature required for the crafts we are talking about: Faience and glaze required about 1200 degrees centigrade of heat[31]; annealing of copper would require a temperature above 500 degrees centigrade[32]; melting of copper would require above 900 degrees centigrade[33]; making of steatite paste would also require intense firing, above 800 degrees centigrade[34]. The studies in their details show how the artisans at Harappa mastered the art of controlled heating without over-firing most often, producing a range of objects from the minute faience vessel and beads, stoneware bangles, steatite glazed seals and paste glazed wares to copper vessels and artifacts. Further testing and analyses are awaited to get a complete picture of the pyrotechnology used at Harappa. At the present state we understand the Harappan artisan to have dealt with problems of designing high temperature apparatus and handling heat resistance, insulation, and atmosphere control at high temperature with apparent finesse. The character of the site as one focused on craft is brought out by the findings. Highlighting this character of the site, Miller concludes that a relative study of pyrotechnology involved in different sectors of craft production would provide clues to factors of new inventions during processing, and of control-of-production knowledge. This will add to the data regarding connections between crafts, control

of industrial crafts, locational factors indicating control level, etc. What is of further interest to a social historian of early technology are such associated factors: like the kind of fuel used for generating such high temperature and the meaning this might have on the ecological condition at and near the site concerned.

There were other simpler crafts flourishing at the site, which required a regimen of applied chemistry apart from these special craft jobs requiring a high temperature activity. The whole repertoire of Harappan ceramics reveal that possibly there were several different grades of work units producing the various types of pottery for the Harappan population. The Harappan potter of the simple ware was no less a specialist in his own line. The task of manufacturing the signature ceramics of the Mature Harappan culture required stage-by-stage production sequence in all of which applications of a working chemistry formed the core principle.

First stage involved the preparation of the clay. The pottery generally found at the Harappan sites, both plain and decorated, were made of good variety of clay that burned pink or light red in colour. It required little or no tempering. But Ernest Mackay put forth that a kind of clay containing iron compounds was used deliberately by the Harappan potters to make the dark variety of ware, for example, the Grey Ware[35]. The analyses of Harappan ware reveal the use of tempering material for the hard pots they created. The tempering materials used with clay were mica, sand and lime. These were often used singly and rarely in combination.

The prevailing natural tints of the brick, pottery and miscellaneous terracotta objects found in such abundance at the Indus Valley sites are light red or salmon. Black and gray are rather rare. P. C. Ray cites[36] Mohammad SanaUllah, the chemist who checked out the Mohenjodaro findings. Sana Ullah was of the opinion that the colours are due to the presence of iron compounds in the clay, which develop a red shade in the oxidizing atmosphere of the kiln, while black or gray products are obtained when reducing or smoking atmosphere prevails in the course of burning. Evidently little deliberation is needed for this natural tinting. However, we may safely assume the fact that the Harappan potters were adept at controlled firing which would produce the required tint.

Next the potters used a first coating on the pottery, either before or after firing them. This is called slip. This required a deliberate application of some minerals. Pottery analysis shows that the slip of bright red colour sometimes found covering the pottery body is due to ferric oxide, Black slip was obtained by using lamp black or powdered charcoal added to levitated clay. White or cream came from lime pining.

The third stage of colouring is marked by paintings drawn on the potteries after baking. So the paints were composed of organic and inorganic substances. Subsequently due to chemical changes in the process of firing a considerable colour range was achieved.

The Harappan potteries were both monochrome and polychrome but in polychrome wares painting was generally executed after baking.The condition of the Harappan pottery fabric indicates efficient firing. The pottery articles of the Indus Valley are found to be all well – baked. We have already described the principal kilns found at Harappa. The possibility of open firing has also been considered by researchers. However, as evident from the healing processes practiced by contemporary potters, in most cases temporary furnaces were built, which would leave little sign except for residual burning on floor. This may have been responsible for the finding of a limited number of furnaces at the site of Harappa. But controlled firing is evident from the end product.

The logistics of these activities at Harappa have to be understood in terms of the site itself, its location, possible operational zone and links with raw material supplying sources.

The site is situated on the now dry river - bed of Ravi in Western Punjab (Pakistan). The rivers here in lower Pakistan Punjab are entrenched, farming tract is limited. The vegetation around is scrubby. That might offer enough fuel for a generation. But long - term drought could result from a long period of such fuel use. The excavators could conduct works on this line, with a view to graph the settlement archaeology and resource use. A radius of at least five miles would have to be explored with an eye to the signs of palaeobotanical evidences of the type that has been carried out in Rajasthan by Gurdeep Singh[37]. The time has come to look at the historical problems from a holistic angle. The Harappan requirements might have had effects on a greater area of contemporary settlement life.

In general it is accepted among recent batch of archaeologists that the human activities at an early site normally extended up to a radius of five miles around the discernible boundaries of the habitations at the site itself. For a large site like Harappa, with its development into a metropolitan center in the region, we may safely assume an extended activity zone. This zone supplied the basic lifelines to support the secondary and tertiary activities at Harappa. In fact prior to M.R. Mughal's findings in the Sutlej – Indus divide, the problem of Harappa's existence had loomed large before scholars. M. R. Mughal's Bahawalpur and Cholistan desert findings provide clue to how the site of Harappa developed into a major outpost center in the upper Punjab, on the route to northern trading towards central Asia and Afghanistan. It is now evident that the Indus-Sutlej divide running at a straight line to the east from Harappa housed several Nature Harappan villages and small towns even, with a scattering of camp sites too. It is also important to note what resources the site commanded southward. This would entail our looking at some of the major items that featured in the exchange trade of the times throughout the context of Harappan Culture.

On these lines we would like to put forward certain suggestions made since earlier times regarding the source of copper used at Harappa, to show how far extensive the resource utilization at a site could affect contemporary settings. Meadow and Kenoyer have already referred to this angle of study when they say: "To unravel the complicated stratigraphy...and to relate associated artefactual and ecofactual materials with different phases of construction and destructions has required that small scale excavation be balanced with large scale clearing."[38]. The large scale clearing is conducted with a view to reveal possible signs of resource use outside the boundaries of the site proper. One pointer draws our attention to the possibility of the Harappan craft industry exercising control over the resources of the neighbouring region. This is true of the possible resource area for copper, which has been identified as connected to the copper belt in Rajasthan). In this connection the Ganeswar[39] and Ahar cultures[40], both of which give the earliest time bracket from the mid third millennium BC., could be said to have played a certain role. Moreover, recent findings of N.Kochar, R.Kochar and Dilip Chakrabarti would show that the Harappans might

have had a possible source for tin ore in the belt running from District Bhiwani of Haryana, running down into Rajasthan[41]. Incidentally, Ambaji is also rich in tin ore[42]. Tin was found to be present in 67 copper specimens from Indus civilization. On the other hand another important pointer is the findings of steatite. It is interesting to note that Heron had recorded the occurrence of a long discontinuous schist belt, rich in various forms of steatite starting from the region of Ambaji in Sabarkantha district through Sehore, Ajmer and Jaipur districts of Rajasthan upto Punjab[43]. The control or contact mechanism of the Harappans at Harappa would have to be worked out to identify the actual radius of resource utilization, set up by the Harappans. The problem at the site of Harappa regarding the availability of ore and lack of evidence for local smelting could be approached from this angle. I have already dealt with the question of possible contacts between contemporary Rajasthan chalcolithic cultures and the Harappan sites of Kalibangan and Harappa in other essays[44].

Having pointed out the complex problematic of assessing the resource use at a metropolitan site like Harappa in the protohistoric context, we might take a hypothetical shot at the effect that the high - technology activities at Harappa might have spelt for the surrounding countryside. About the location of Harappa, Marcia Fentress had rightly pointed to the fact that compared to Mohenjodaro, "Harappa's natural hinterland, comprising the Sulaiman Range, the outer Himalayas, the eastern Doab and northern Rajasthan was a much richer and more diverse area. Harappa had access to diverse and rich resources almost within its own geographical region." (45). Shereen Ratnagar,[46] has also pointed to this nature of the site and comments, "Thus, Harappa is in a situation of maximum advantage for procuring goods..." On the basis of traceable link routes radiating out to the north, south, east and west from Harappa, Ratnagar extends the hypothesis that, "at least at Harappa, the processes of urban growth were related less to increasing rural productivity and the proliferation of local exchange systems than to redistributional mechanisms and an external trade orientation." If we accept the truth in this view, it appears that the resource utilization at and around Harappa was geared to external exchange and the human activity resultant

on the environs of the site would appear to have been generated by extraneous factors. It is important to note that all these raw materials were used for productions where chemical processes were largely involved. Much of the operations moreover required high temperature firing. Therefore, the factor of fuel use comes in for consideration, if we are to assess the total dimension of the production technology for the Mature Harappan context at Harappa. The ethical evaluation of the natural resources depreciation resultant upon the high – firing technology at Harappa would emerge to be an interesting, relevant issue in a total assessment of the protohistoric developments in South Asia.

Besides emphasizing on the peripheral activities at a distance from the site, we would like to point to the activities at the site itself. The physical evidence of artifacts as well as signs of their production inside the site, now revealed, increasingly in Meadow's continued excavation would also point to craft activity at Harappa, in which the applications of chemistry as a part of working knowledge appear to have been substantial. Not only are we talking in terms of the stage by stage specialized operations where chemical processes played a major role, but we also need to start with the fact of how the whole operation began with the exact identification of the raw material for such operations. Two things are important here, viz., (a) the gathering knowledge about the properties of the natural raw material along with the knowledge of knowledge of possibilities of the materials when put through chemical processing; and (b) the identification of the source of these raw materials. In the last case as we have seen they were collected from sources located at great distances from the actual site where they were worked. Should we then try and also trace the contemporary work units nearer to the sources. In some cases, like that of Rajasthan copper mines, this was found to be a reality. The growing knowledge of technology through innovations, new applications of this working knowledge of scientific and technical nature had gathered momentum since the PreHarappan days. In this chapter we had only taken a glimpse at one aspect of this development at the particular site of Harappa. We should realize we are talking about a civilization dating back to almost five thousand years, when minute specialization division between handicraft production and distribution network running in raw materials

as well as finished commodity may not have existed. Do we not see the handicraft / artisan and merchant guilds combining in single units of operations in the early historic times in India? The significance such institutional formation could have had on the contemporary society is another matter for protracted study. Suffice it to say here that Harappa as a site stands as an example of the importance of the science and technology and the exchange network in the context of this complex culture. The effect of such exchange pattern on the natural habitat in each ecological – cultural unit is yet another matter for research.

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Minerals and their Processing in Indian Antiquity and 20th Century

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This article seeks to provide a panoramic view of minerals and their processing in Indian antiquity, and then, a contemporary view of the 20th century developments and the problems we face in the 21st.

Dana's System of Mineralogy defined a mineral as a 'naturally occurring crystalline element or a compound having definite chemical composition, and formed as a product of inorganic processes'. The definition is now considered to be too restrictive. The synthesis of new 'minerals' at high pressures and temperatures, discovery of new amorphous forms, biologically precipitated materials etc., have put mineralogy at a cross-road. Both the scientists and archaeologists have legitimately taken broader interest in 'materials' all of which are not covered under the title 'mineral'.

Hemley marked Theophrastus, the author of 300 BC text-book *De Lapidibus* introducing 16 minerals, as the founder of the science of mineralogy, but we believe that India (not Greece) was the first country where precious stones and minerals were studied in great depth. Similarly, in metallurgy also, Indians were the pioneers during the ancient and medieval periods.

Based on a series of articles and books by the present author,[1-8] the present article is structured chronologically :

- The ancient civilizations including the Pre-Harappan.
- Minerals and metals in the Harappan era (3200-1800 BC).
- The transitional period and the Vedic literatures on minerals and metals.
- The Iron Age in India (1200 BC to 600 A.D.).

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— Taxila and the primacy of India in brass and zinc metallurgy.
— The *Ratnaśāstra* texts.
— Medieval zinc technology in India.
— Iron and crucible steel in pre-modern India.
— Factors underlying medieval stagnation in the Indian science and technology, and lastly.
— The 20th century scenario and mineral engineering profession.

Materials in the Pre-Harappan Civilizations of India

Mehargarh in Baluchistan, Pakistan has revealed a eighth-sixth millennium BC pre-ceramic neolithic culture showing flint tools, grinding stones, barley, wheat, cereal cultivation, cakes of red ochre, beads of shell, turquoise, lapis lazuli and a cylindrical shaped copper bead (MASCA C-14 date 7786 ± 120 BC). Phase II (6th-5th millennium BC Culture) has revealed soapstone beads, flint drills and copper ring and bead. The first half of 5th millennium BC showed crucibles used for melting copper, some metal still adhering (4745 ± 90 BC MASCA C-14 date). The Mehargarh evidences have negatived the earlier view expressed by Agarwal that the metallurgical know-how had diffused to India from Tal-i-Iblis, Iran for which Caldwell provided a date of 4000 BC. It may now be safely asserted that copper metallurgy was developed indigenously in the Indian sub-continent and well before 4000 BC. There had been sizeable copper ore deposits in the Zhob district for the people of Mehargarh to smelt.

The clearest evidence about the Pre-Harappan chalcolithic culture in India has been obtained in the Ganeshwar-Jodhpura area near Jaipur, Rajasthan. This site yielded huge quantities of copper objects such as blades, arrowheads, fish-hooks used in the Pre-Harappan Sothi culture and later in the Harappan culture. Deeper digging has shown earlier stone age culture, proving that Ganeshwar gradually moved from the neolithic to the chalcolithic stage before the Harappan era.

Minerals and Metals in the Harappan Era

Considerable information on the Harappan civilization in

India (3200 to 1800 BC) has been obtained from the works of John Marshall, E.J.H. Mackay, M.S. Vats, S.R. Rao, the multi-authored volume edited by G.L. Possehl etc. Mohenjo-Daro, Harappa and Kalibangan were the principal metropolis towns. Mohenjo-Daro, was definitely the grandest, exhibiting a bewilderingly large variety of materials. We may list some of them. Semi-precious stone bead industry was widespread in the Harappan civilization which used rock crystal or quartz (SiO_2) and varieties of chalcedony (SiO_2, nH_2O, sometimes waxy) such as: carnelian (sard pale to deep red, reddening due to dehydration of yellow hydrated ferric oxide in the industrial process), chrysoprase (apple-green due to nickel), plasma (bright to emerald green), heliotrope or blood-stone (plasma with red spots), agate (banded, different coloured chalcedony), onyx (agate with straight bands, even planes), felspar/microcline ($KAlSi_3O_8$), amazonstone (green, twinning striation microcline), nepheline or sodalite. Lapis lazuli, turquoise and jadeite were probably imported. Amongst other materials found were : potteries, clay, brick, limestone, lime and gypsum as mortar, faience and vitreous paste suggesting the use of *reh* or alkaline river incrustation and colouring flux, sandstone, steatite or soapstone containing talc, basalt, bitumen, *silajit,* a black coal-like organic medicine, pigments such as white gypsum, red/yellow ochre, purple-black manganiferous oxide, green *terre verte* or green earth (glauconite or chlorite, an iron silicate found in the basalt of Bhuswal in Central India) etc. Whereas the city of Harappa did not show as many varieties of materials as in Mohenjo-Daro, some of the special materials found there were : coral, mica, yellow arsenic or lollingite for bronze metallurgy, scrap bronze used as source of tin, yellowish limestone, grey granite, terracotta animal toys, finer textured potteries etc. Harappa was an important manufacturing centre, there being many more furnaces than in Mohenjo-Daro. Fa, Fe and Fj furnaces definitely produced metals, since crucibles and slags were found there. Crude copper ingots found at Harappa probably came from Rajasthan and Hakra (Sarasvati river bed now in Pakistan) areas.

Chanhudaro was an important workshop centre producing seals and beads made of steatite or soapstone, the main constituent of which is talc $Mg_3Si_4O_{10}(OH)_2$, which is one of the softest materials known. Gujarat steatite contains some kaolin-

type aluminium silicate, which is also soft. Hegde has demonstrated that when this material is heated, it is hardened (Moh's scale of hardness rising from one to seven) on account of formation of silica (crystobalite) and enstatite (anhydrous magnesium silicate).

To produce the steatite seals, steatite rock was cut and then often coated with steatite paste. Hegde has conjectured the following method of preparation for hollow steatite micro-beads : A paste of finely ground talcose steatite was probably squeezed through 1mm. diameter perforations having 0.5 mm. diam copper or bronze wires in centre to produce hollow tubes. These were then cut into small pieces, dried and hardened by firing above 900°C. The Harappans did not know chemistry or material science, but their empirical technology nevertheless bespoke of ingenuity!

A variety of gold ornaments were used by Harappans. The prolific use of silver was confined to the Late Harappan era. Lead was used for plumb bobs and even for better fusibility in copper casting. Copper technology was of course the most noteworthy. Arsenic, tin and nickel were used to alloy copper, but their sources are difficult to locate. Löllingite (Fe_3As_4) and scrap bronze (source of tin) have been obtained as archaeological specimens. Agrawal analysed some 177 copper artefacts of which 8 p.c. contained arsenic and 4 p.c. contained nickel. Only 30 p.c. contained any tin, and 20 p.c. artefacts assayed 8-12 p.c. tin, suggesting some standardisation in the process of alloying.

The Harappan tool repertoire comprises of razors, knives, chisels, thin arrow-heads and spear-heads, axes and fish-hooks. Metallographic examination of the artefacts indicated knowledge of slow-cooling of the cast, annealing and cold work etc., possessed by the Harappans. Even lost wax or *cire perdue* process of casting was known to them as shown by the dancing girl figurines from Mohenjo-Daro.

The indigenous nature of the Harappan copper industry has been specially investigated. Both the sulphide and oxide ores were used for reduction to copper metal. Large quantities of copper oxide ore were discovered from a brick-lined pit at Mohenjo-Daro. Agrawal has conducted very useful ore-artefact correlation. He suggested that Chanhu-Daro celt and Mohenjo-Daro spearheads were made from Khetri chalcopyrite ore, since

all the three materials contained trace impurities of Sb and Pb but not Fe and As.

Similarly, Hegde performed spectrographic analysis of two copper samples (an axe and a sheet) from Late-Harappan site of Ahar and of the Khetri copper ore, all the three from Rajasthan. The samples showed traces of elements such as Pb, Ni, Co, Fe, Mn, Zn etc. and absence of elements such as Au, Ag and Sn. This positive ore-artefact correlation suggested that the Ahar metal might have been made from Khetri ore.

The present author has however argued that even such correlations are not conclusive.[1] For conclusive evidences on indigenous technology, we should look for mines, metallurgical production units, artefacts at different stages of manufacture, heaps of slags and slag-ore correlation. Fortunately, several such evidences for indigenous metallurgy in India have been obtained from Mehargarh, Ganeshwar-Jodhpura, Chanhu-Daro, Ahar, Khetri (for copper), Atranjikhera, Ujjain (for iron), Zawar (for zinc) etc. Ahar for example has shown heaps of slags which have been analysed.

The Transitional Period and the Vedic Literatures

The transitional period between the Harappan to the Historical eras namely 2000-800 BC has been characterised by several interesting features. A number of experts have concluded that the collapse of the Harappan civilization was not on account of any 'foreign invasion' but essentially due to repeated floods, tectonic movement leading to the drying up and disappearance of the Sarasvati river, civil war, loss of trade etc. The Ṛgvedic civilization, which was most probably the Sothi Culture on the Sarasvati river, and very much a part of the wider Indus-Sarasvati Valley civilization, moved eastwards in the search of perennial water. Harappans also moved to the southern India. During the said transitional period we come across two chalcolithic cultures : 'Copper Hoard' in the east, alloying copper more with arsenic, and 'Peninsular' in the south preferring tin and lead as alloying elements. In quest of fresh raw materials and alloying elements, chance discoveries had been made. The Rangpur, Gujarat, a Post-Harappan (2000-1300 BC) site showed copper objects containing nickel : a celt assayed 2.1 p.c. nickel and a pin 5.88pc. nickel. Nickel in these samples was probably

derived from the Rupavati ore in the neighbourhood and not an intentional addition.

The story of zinc also started during this period. The present author has claimed that the earliest brass anywhere in the world is from the Harappan site of Lothal: No. 4189 copper object at 1500 BC. Lothal assays 6.04 p.c. zinc. Harappan Rosdi also produced chisel, celt, rod and bangle containing up to 1.54 p.c. zinc. A part of a chariot in submerged Dwarka circa 1500 B.C. assays 10.68 p.c. zinc, 1.32 lead, 0.43 iron and rest copper. The Iron Age site of Atranjikhera (ca. 1000 BC) produced heavily allowed copper objects : one assayed 6.28 Zn, 11.68 Sn, and the other 16.20 Zn and 20.72 Sn. The present author has drawn attention to these early samples of cementation brass and their possible link with the 1260 ± 160, 1136 ± 160 and 1050 ± 150 BC, C-14 dates of the timber samples in the Rajpura-Dariba silver-lead-zinc ore mine near Udaipur. We would continue to describe the saga of bronze and zinc in India later.

The Iron Age in India

Iron came later in human civilization compared to low-melting tin, lead and copper which could be easily reduced from their oxides and melted. Thermodynamically, iron oxide can be reduced to iron at any temperature above 800°C, but since the melting point of the metal is 1540°C, the ancient furnaces having a temperature in the range 1100-1200°C could result only in solid state reduction of iron oxide. Caught up in the reduced spongy solid mass used to be molten slag which had to be squeezed out by hammering and forging. The ancient smith took a long time to understand the intricacies of solid-state reduction and the fact that the soft mass of iron could be hardened and made useful only through prolonged contact with charcoal (the process of carburization).

The dates of the earliest iron age sites in India show that the discovery and use of iron started around 1200 BC indigenously and independently in at least three nuclear zones-Karnataka area in the south, U.P. - Rajasthan area in the north and West Bengal-Bihar area in the north-east. The evidences of early experimentation justify the theory of indigenous origin. Since iron could not be melted and cast easily, carburization of thin sheets of iron in charcoal fire and subsequent lamination

and forge-welding of alternate layers of uncarburized and carburized sheets proved to be a spectacular and useful Indian discovery made much before the era of laminated Egyptian knife dated 900-800 BC.

The earliest evidence of hardening through quenching and tempered martensitic structure (characteristic of steel) obtained so far, pertains to a third century BC iron sickle from Pandu Rajar Dhibi in West Bengal. The iron tool types went on evolving with progress of time. Prakash and Tripathi (1986) divided the period of evolution into three long stages : Period I (1200-600 BC), Period II (600 to 100 BC) and Period III (100 BC to 600 A.D.). The marvellous and rustless Delhi Iron Pillar was built by Candragupta Vikramaditya (375-413 A.D.). This forge-welded 1600 years old structure is made of wrought iron (0.15 p.c. carbon). Its astounding corrosion-resistance is partly due to its composition : high slag and phosphorus (0.25 p.c.) content and low manganese (0.05) and sulphur (0.005) content. This is one of the 'wonders' of the world.

Taxila and the Primacy of India in Brass and Zinc Metallurgy

The 5th to 2nd century BC era of the Nandas and Mauryas was a golden period for mineralogy and metallurgy in India. This is attested not only in the writings of Panini and Kautilya but also in the archaeological treasures excavated at Taxila. Situated 22 miles north of Rawalpindi in Pakistan, Taxila displayed long and sustained civilization from 500 BC to 400 A.D. from the eras of the Nandas and Mauryas to the era of the Guptas.

Excavated in Taxila were many gold and silver jewelleries, gems, inlays, intaglios, metal coins and beads. For making the beads, the principal minerals used were carnelian, agate, quartz, malachite, lapis lazuli, garnet, jasper etc. arranged in decreasing order of abundance. Evidently, lapis lazuli continued to be imported, carnelian produced indigenously, and beryl exported. Shell and faience beads were also very common. Glass beads were of seventeen colours, the most popular ones being green and blue. Presumably, these were imitations of beryl and lapis.

Taxila displayed huge number of artefacts made of iron and copper, both pure as well as alloyed. The principal alloying

elements were tin, lead, antimony, nickel and zinc, while traces of iron and arsenic had got into copper as impurities. Taxila produced soldering alloy containing 50 p.c. lead, 46 p.c. tin and 3 p.c. copper. Around 1 p.c. antimony in several copper samples seems too low to suggest deliberate alloying. Probably, the antimony-rich copper ore from Badakshan, Balkh and Kabul might have been tapped; this type of ore also resulted in the Taxilian white opaque glass (5.08 p.c. Sb_2O_3) and turquoise blue powder (2.42 Sb_2O_3 and 3.6 CuO). During the medieval period, antimony sulphide of this region was indeed used to make high-antimony *Khārsini alloy*. In Taxila, 'white copper' alloy (known as *pai-tung* in China and *packtong* in Europe) used to be made containing nickel, 9 p.c. in the early third century BC samples, and later a fairly regular proportion of 19-21 p.c. This ductile alloy was valued for its silvery lustre and employed for jewellery, coinage etc. Appearances of antimony and nickel in the copper artefacts of Taxila were indicative of trade contacts with Afghanistan and China.

Taxila provides us with a link in the continuity of our narrative on brass and zinc in India. We have referred to the earliest brass in Lothal and Dwarka and then Atranjikhera. India continued to make brass through the cementation route, namely reduction of copper ore and zinc ore in the same furnace simultaneously. While zinc oxide is easily reducible at the usual temperature of the smelting furnace, the metal zinc is produced in the vapour state, since it has a low boiling point 917°C. Zinc vapour gets absorbed in copper to produce cementation brass.

It has been proved through replication experiments that the cementation process cannot give brass containing more than 28 percent zinc. Therefore, we cannot fail to note the overriding importance of the vase (BM 215-284) excavated from the Bhir Mound at Taxila and dated fourth century BC which was before the Greeks arrived in India. This brass sample contains 34.34 percent (much more than the critical Figure of 28) zinc, apart from some tin and lead. The sample must have been made through mixing of pure zinc and pure copper, and provides very strong evidence for the availability of metallic zinc in the fourth century BC. Now it is accepted that India was the first to make this metal zinc *(rasaka)* by the distillation process as practised for the other metal mercury *(rasa)*. The ancient Persians tried in vain to reduce zinc oxide in an open furnace when the reduced

zinc vapour quickly reacted with air to give back white dust of zinc oxide! The Indians empirically discovered the art of closed retort reduction and condensation of zinc vapour in a reducing atmosphere.

The ancient zinc ore mine at Zawar, 30 km. south-west from Udaipur, has revealed C-14 dates of timber such as 430 ± 100 and 380 ± 50 BC etc.. Willies has provided vivid description of the ancient zinc mines of Rajasthan, particularly the Zawar Mala mine, where Hegde identified several five liter capacity pear-shaped pots as Ahicchatra 10A type pottery datable to the last quarter of the first millennium BC. The second century A.D. text *Rasaratnākara* of Nāgārjuna referred (1.31-32) to the reduction-distillation of calamine yielding zinc : "an essence of the appearance of tin". It seems that the Greeks closely followed the Indian developments in the fields of brass and zinc technology. Their term for brass was 'oreichalcos' which was adapted in Sanskrit during Kautilya's time as *ārakūta* (just as Greek 'cassiteros' for tin was converted to *kastira* in Sanskrit). Eventually, however, the Sanskrit term for gold-like yellow brass was *pīta-tāla* (yellow alloy) or *pitala*. In view of the Indian quest for substitute gold, the name for zinc was changed from *rasaka* (that which is distilled like *rasa* or mercury) to *yaśada* (that which gives *yaśa* or fame alluding to gold). It is this Sanskrit word *Yaśada* which was converted to *dastā* in the other Indian languages and 'zinc' in the European languages.

The Greeks appear to have carried back to their country a sample of Indian zinc as souvenir. In the course of the excavation of the Agora in Athens, a roll of sheet zinc was found in a sealed deposit and this has been dated to belong to the third/second century BC. Analysis showed it to be nearly pure zinc with 1.3 p.c. lead, 0.06 Cd, 0.016 Fe, 0.005 Cu with traces of Mn, Mg, Sn, Ag and Sb. It is well-accepted that the Greeks never made any such thing themselves during 3rd/2nd century BC. Most possibly they carried this material from India and this can be confirmed through trace analysis and lead isotope ratio matching between the cited sample and Zawar ore. Ever since 4th century BC India has been the only country in the world to make pure zinc and high-zinc brass. The technology of reduction-distillation of zinc was developed through centuries, and we would describe it (as it stood during the medieval era) later.[7]

The Ratnaśāstra Texts and the Trade on Gems

The science of gemmology in India started with the 4th century BC *Kautilīya Arthaśāstra*. We do not know the dates of the early authorities such as Mahākāla or Vyādi. The Indo-Roman trade picked up during the turn of the millennium and prospered during the post-Christian centuries. Following this Graeco-Roman trade on gems, the Ratnaśāstra (gemmology) texts were compiled by successive authors in India. The Tamil text *Śilappadikaram* was compiled during 2nd century A.D.. The 5th century A.D. texts *Bṛhat Samhitā* of Varahamihira and *Ratnaparīkṣā* of Buddhabhatta were outstanding. Many more texts were written upto 13th century A.D.. Many of the original texts have been published with translations.

The ancient Indians were attracted by the lustre and colour of gems which they tried to categorise in terms of colour. This led to some confusion since two entirely different gem minerals could show the same colour. Hence relative hardness was introduced as an important criterion in distinguishing one from another. Density or specific gravity was also recognised as an important property of the gem minerals. Dichroism, the property of some transparent gems of exhibiting two different colours, when viewed through perpendicular directions, was known. Birefringence *(dvichhāyā)* of calcite-like minerals was also observed. The Indians processed a wide variety of gems starting from the hardest diamond (Moh's scale of hardness ten), corundum (nine) down to talc (one), pearl etc.

The sources of diamond (mines) in India were keenly investigated in the *Ratnaśāstra* texts as well as by the Roman authors. Early literature refers to *ākara* (mine of diamond) and *ākarāvanti,* Avanti the mining town. The crystalline properties of diamond were noted : eight symmetric facets *(samaphalaka),* twelve sharp edges *(dhārā),* six prominent solid angles (koṇa) etc., (in the text *Rayanaparikkhā,* 23-24). Diamonds were classified in terms of transparency, colour and 'castes'. The price of a crystal increased with approximately the cubic power of the mass or size. With a tenfold increase in mass (from 2 to 20 *taṇḍula* or 4 carats), price increased approximately 1000 times. A text (Agastimata 50) suggested that diamond is approximately four times heavier than water. Its specific gravity is now taken as 3.52. The traders knew that relatively heavier pieces were

impure; the usual impurity zircon has a higher specific gravity 4.68.

Both diamond and corundum powder were widely used as abrasives. Corundum was used to polish Aśokan sandstone pillars and exported to Rome for marble-sawing and polishing gems. Pure Al_2O_3 lattice corresponds to colourless *Kuruvinda* (corundum) and some substitution in the lattice by chromium makes it red *padmarāga* (ruby) and iron or titanium in the lattice makes it blue *indranīla* (sapphire). The substitution lowers the surface free energy and hardness to some extent. Although the theory was not known, Buddhabhatta correctly observed *(Ratnaparīkṣā,* 137) that corundum is slightly harder than ruby and sapphire. Asterias or star sapphire is a chatoyant star, reflecting light from the surface of microscopically small tubular cavities. *Kautilīya Arthaśāstra* (2.11.31) described this as *śravanmadhya* or 'streaming interior showing rays shooting like flowing water'.

We may now mention beryl, a very important gem of India. The present author has presented elaborate discussion on the etymology and trade of beryl *(vaidūrya)* and emerald or *marakata.* Emerald was well-known to Indians as an Egyptian *(masāra)* gem *(galu),* masāragalu or masāraka and also as marakata, the gem which is obtained from a mine (in Egypt) which is reached after one crosses the desert *(maru)* and the coast *(kata).* The etymological links between (a) veluriya-beryl and (b) masāraka-smaragdos-esmeralda-emerald indicate the power of the Sanskrit language and the primacy of India in gemmology.[8]

We may cite another glorious example of the twin primacies of India in the fields of gemmology and linguistics. The *Periplus* has documented that India exported ivory to the Graeco-Roman world through Barugaza in Gujarat, which had a sizeable population of elephants. Schoff recorded how the Sanskrit word *ibha* (elephant) and *ibha-danta* (elephant's teeth) were converted to abu in Egyptian, Semitic article *el* prefixing *ibha-danta* to give *elephas* in Greek, and the English words 'elephant' and 'ivory'!

Zinc Technology in Medieval India[7]

Even though Hindu science and technology suffered

stagnation and decay after the collapse of the Gupta dynasty in the fifth century A.D., it survived beyond 1200 A.D., a date which marks the onset of the medieval period in India and when the Muslims established their stranglehold on a sizeable part of the sub-continent. Of course the Muslims could not dominate over several other regions in the country such as the Hindu Kingdom in Udaipur, southern Rajasthan, where zinc technology reached a developed stage in the 13th century A.D.. This technological outfit has been recently discovered archaeologically in 1983-1984 and described in detail by Hegde and the present author.

The excavation in Zawar revealed an extensive arrangement of furnaces with retorts 30-35 cm long and 10-15 cm diameter. There were 36 retorts in a 6 x 6 arrangement contained within the truncated pyramid of each furnace. The retorts were supported vertically on perforated bricks through which the condenser tubes passed into the cooler zinc collectors beneath. This arrangement of downward distillation retort with the condensing unit underneath is precisely what had been described in *Rasaratnasamuccaya* (RRS 2.157-166; 9.48-50). The brinjal-like retorts in Zawar are also similar to the *vṛntākamūṣā* described in RRS (10.22-23).

Sphalerite with impure dolomite and quartz was mined, crushed, ground and mixed with a small quantity of common salt and a large quantity of carbonaceous matter. The charge (about 1.5 kg. per retort) was loaded into the retorts, fitted with the funnel-like condenser tubes, and heated externally, possibly at 1250°C for six hours. The reduced zinc vapour was condensed and collected. It is likely that 200-500 gms of zinc were extracted per retort, or 7-18 kg per smelt of 36 retorts. A part of the zinc oxide was converted to well-identified silicate phases and thus could not be recovered as reduced metal. At present there are 8 lakh tons of debris at Zawar containing 6 lakh tons of spent retorts. Each retort weighs about 3 kg. and might have produced 500 g. of zinc. On this basis it is estimated that about 0.1 million tonnes of zinc might have been produced at Zawar during the 13th-18th century A.D. period.

The technology became extinct by the end of the 18th century on account of the repeated invasions of the Marhattas. However, during 1720-1743 there was a technology-transfer from Zawar in India to Bristol in England. Craddock et.al., have conceded that some Englishmen had visited Zawar, and William

Champion's 1743 process 'was notoriously close with details to the Indian process at Zawar'. They have also noted with satisfaction that this technology-transfer is 'a striking example of continuity and the reciprocal nature of scientific and technological development throughout the world'.

The Zawar technology had been kept a well-guarded secret; Abul Fazl in Akbar's Court knew nothing about the details. As late as 1751 A.D., *Postlewayt's Dictionary of Trade and Commerce* admitted ignorance about zinc technology. While the rest of the world manufactured brass by the cementation route only, and none of this assayed more than 28 p.c. zinc, India alone produced high-zinc brass. The artisans of Bidar (83 km from Hyderabad in South India) produced during the 15th century A.D. 'Bidri' alloy, containing as high as 76-98 p.c. zinc, 2-10 p.c. copper, at times 1-8 p.c. lead, 1-5 p.c. tin and trace of iron. Vessels made of Bidri alloy were darkened by applying a paste of ammonium chloride, potassium nitrate, sodium chloride and copper sulphate. The precise composition of the amorphous black patina is not known; scanning electron microscopy reveals that the 10μm thick surface assay 30 p.c. copper as a contrast to 3 p.c. in the bulk. Before the blackening procedure, appropriate design used to be engraved on the vessel, and on this, silver, brass or gold wire was inlaid or encrusted. After blackening, washing and polishing, the Bidriware—a *huqqa*, ewer, bowl or *pan* box—appeared as a lustrous dense black body contrasting with the brilliant lining or inlay : white (silver) or yellow (brass or gold).

Iron and Crucible Steel in Pre-Modern India

Valentine Ball recorded the diversity of iron ores mined, purified and processed by the iron smelters of pre-modern India, citing the reports of the earlier workers. In medieval India, three types of furnaces were used for smelting : small blast furnaces (4-5' feet high), tall blast furnaces (typically 10' feet high) and bowl-shaped open hearths. India produced three kinds of products : crude wrought iron, pure wrought iron and high-carbon wootz steel made in crucibles. The 13th/14th century A.D. text *Rasaratnasamuccaya* (RRS 5.70-99) cited three kinds of iron : *muṇḍam* (wrought iron) which could be *kuṇṭham* or *kaḍāram,* less ductile containing some carbon, second variety *kāntam* (magnetic or made from magnetite), and third *tīkṣṇam*

(cast or carburised iron or steel) which again was known in six varieties to be described later.

It is quite likely that there were some foreign interactions with the iron and steel industry in India during the Mughal period. Some of the South Indian iron-making furnaces (10-15' feet high, 3' feet diameter) resembled Stuckofen smelters in Germany; Dutch influence in the design of this kind of furnace cannot be ruled out. The Dutch were consumers and even producers (in the Orissa coast) of Indian iron and steel. The iron industry in Kathiawar had furnaces of unusual shape : 'something of the nature of a reverberatory furnace', the development of which might have been assisted by some European technicians. Some Chinese influence was evident in Upper Assam where the smiths used contrivances quite different from those used in India proper. They used special blowing machines : single-acting or double-acting blowing cylinders, which substantially raised the temperature of the charcoal-fired furnace.

Bennet Bronson has wondered how early was wootz or crucible steel made in India, and grudgingly conceded that it could have been as early as second century A.D.. Excavations have revealed crucibles dated 250 BC in Tamilnadu. *Kautilīya Arthaśāstra* (2.12.23, 2.17.14, 3.17.8, 4.1.35) repeatedly mentioned *vṛtta* which is carburised iron or steel. Vṛtta means circle and denoted crucible of circular cross-section in which wrought iron was fused with carbon. The word was changed to wootz in South India (*wuz* in Gujarati, *ukku* in Telugu).

There were two distinct processes for making *wootz*. The process practised in Sri Lanka, Tamilnadu and Karnataka merely carburised wrought iron in crucibles. The Persians were interested in the second process practised in Golconda or Konasamudram, Hyderabad, described in detail by H.W. Voysey.

Voysey's report refers to a process of co-fusion in which 'moderately compact' cast iron of a 'brilliant white fracture', probably having more than 3 p.c. carbon, was converted to *wootz* (various samples of ingot, blade, dagger and sword assay 1.1 to 1.874 p.c. carbon, many in the 1.6-1.7 p.c. carbon range) by melting it with wrought iron. Prolonged fusion for 24 hours and *repeated annealing* were observed and reported by Voysey indicating that the end product was not simply carburised iron but malleable steel 'sufficiently soft to be worked' like Damascus

sword. This contradicts Bronson's notion that *wootz* was merely carburised iron.

Sherby and Wadsworth have suggested that high-carbon *wootz* cakes were probably forged at not-too-high a temperature: between 'blood-red' 650°C to 'cherry-red' 850°C, and then heat-treated by quenching, to produce damasked sword. They authenticated their suggestion through replication experiments. This is also attested by the vivid description of Tavernier, the French traveller, made in 1679 :

> "The steel used by Persians is brought from Golconda (Hyderabad), and is the only sort of steel (anywhere in the world) which can be damasked. For, when the workman puts it in the fire, he needs no more than to give it the redness of a cherry; should he give it the same heat as to ours (higher temperature), it would grow so hard that when it came to be wrought, it would break like glass".

The unique thing about Indian *wootz* was that annealing at less than 850°C made it hard as well as ductile. Attempts made by famous scientists such as Faraday to simulate wootz failed, because they were trying higher temperature for annealing.

Three centuries before Tavernier, six varieties of tīksnam or steel were described by Vāgbhat in his *Rasaratnasamuccaya* (RRS 5.75-5.82). *Pogaras* meant hair-like lines which may be surmised as white cementite streaks. The *Khara* variety was brittle with 'mercury-like shining fracture surface' (RRS 5.76). *Hṛnnāla* was very hard, and *vajra* was full of hard *pogaras*. The best was *kālāyasa* : 'bluish black, dense, smooth, heavy, bright and its sharpened edge not spoiled by hammering'. This description is close enough to that of the damascened steel swords 'of a dull blue colour and with meandering lines', which have compressed and elongated cementite grains or streaks in pearlite-graphite-martensite matrix. The excellence of Indian *wootz* was attested by the great scientist of the modern era, Michael Faraday.

Factors Underlying Medieval Stagnation in India

Having documented India's primacy in mineralogy and metallurgy, from the pre-Harappan era 7000 BC to the Gupta Period 500 A.D., and having shown that the tradition survived even in the medieval era beyond 1200 A.D., it is now necessary for us to explain the factors underlying medieval stagnation,

not only in the two said disciplines but also in Indian science and technology in general.

Up to 5th century A.D., India was one of the leading nations in the world, not only in the technological fields related to minerals and metals but also in some of the basic sciences such as linguistics, medicine, astronomy and mathematics. India produced a large number of mathematician-astronomers starting from Aryabhat in the fifth century to Bhaskaracharya of the twelfth century A.D.. But the caste system ruined Indian science and technology. The upper caste intellectuals hardly helped or interacted with the low caste artisans. There was widespread secrecy and isolationism in the society. The irrational approaches were hardly countered. Scientific logic was often offset by theological obscurantism. The divided Hindu society succumbed as an easy prey to the Muslim onslaught.

During the sixth to tenth century period, the Arabs took over the intellectual leadership and transmitted to the Europeans in Spain not only the Greek thoughts but also the Hindu sciences such as astronomy and algebra of Brahmagupta. However, it was a different story in India of the twelfth century. While the barbaric Muslim invasion of India was having catastrophic effects on the Indian society, Baghdad itself collapsed under the Mongol invasion. Irfan Habib has candidly described the scenario :

> "That time (after the death of Ibn Rushd or Averroes in 1198 A.D.), science received a setback throughout the Islamic world. There was a heavy onslaught on reason. In medieval India, therefore, Islam was received when the scientific tradition in it was in the process of decay". ....
>
> "The Mughal empire has produced not a single worthwhile text on crafts or agriculture, how many volumes of poetry or histories it might have to its credit. The Indian rulers' refusal to Western science and thought was at par with their indifference to technology".

On account of the rulers' barbarity and indifference, the artisans missed the benefits of the European science and technology. Mining of gem, non-gem and metalliferous minerals was pre-scientific, and the miners had no geological knowledge to pursue through the depleted rocks. The problems related to mines, their drainage, lack of pumps, lack of mechanisation etc. which had earlier been faced and favourably tackled by the

Westerners, continued to haunt medieval and pre-modern India, gasping in vain for solutions.

The indigenous iron and steel smelters of medieval India faced acute shortage of charcoal in the country and lacked the technologies related to coal mining, coke production and superior blowers for the blast furnaces. The cost of production of indigenous iron and steel was going up, and at this stage the British traders, with their newly acquired political strength, started flooding the Indian market with cheap iron produced in big British blast furnaces. Large-scale economic breakdown and loss of political independence resulted in the disappearance of the indigenous industries.

Having gained independence, the Indian sub-continent has again regained hope and faith in indigenous technologies and scientific endeavour. The heroic contributions of the artisans (in the fields of gems, minerals and metals) who toiled through the ages, are gratefully recalled. Their vitality was sustained through centuries, and could not be extinguished either by the Hindu obscurantism, Muslim fundamentalism or British colonialism.

The 20th century Scenario and Mineral Engineering Profession

The British rulers instituted Geological Survey of India (GSI) in the 19th century for their own benefit, and to exploit the Indian sub-continent. They extracted saltpetre from Indian soils for their imperial needs, and mined coal reserves to maintain colonial railway locomotives and steam-ships. However, some benefit did accrue to the Indian population. The GSI and its workers such as Valentine Ball performed commendable work on economic geology and preliminary survey of various mineral deposits in the country. Pramatha Nath Bose, the first practising Indian scientist of the modern era, worked on economically viable iron ore deposits which aided Jamshedji Tata and the TISCO of Jamshedpur.

During the early part of the 20th century, there were several auspicious developments in India : boost in indigenous iron, steel and copper industries, organisation of the coal mines and monazite beach sand deposits etc. Facing the nascent patriotic fervour, the rulers were compelled to initiate graduate and post-graduate education and research in various S & T disciplines, specially in mining, metallurgical and chemical engineering.

Indian School of Mines (ISM), Dhanbad, Indian Institute of Science (IISC), Bangalore, and later Fuel Research Institute (FRI), Jealgora, started developmental work on *beneficiation* of low grade coal and mineral deposits.

After the national independence in 1947, Nehru and Bhatnagar executed a phenomenal expansion in R & D establishments and National Laboratories : IBM, NML, FRI, RRL's, BARC etc., which worked on different aspects of mineral resources development. There was a spurt of industries related to iron and steel, coal washing, cement, copper, zinc, aluminium, uranium, thorium, zirconium, hafnium, chromium, manganese, nickel, titanium and the corresponding raw material resources. Special developmental programmes were taken up to upgrade coal, copper and lead-zinc ores, monazite beach sand minerals, laterite ores containing nickel and cobalt, and recently the atomic energy mineral deposits across the country and manganese sea nodules in the Indian ocean.

Mineral Engineering involves physical and chemical beneficiation after comminution of run-of-mines (ROM) ore, often complex and increasingly (with time) low grade. The components of mineral engineering research are : (a) macro-and micro-characterisation of ore deposits, (b) studies on microprocesses and macro-process modelling of unit operations (UO) and unit processes (UP) such as the 20th century miracle 'froth flotation', linking surface chemistry with separation science and technology, (c) engineering feasibility studies, keeping in mind the specific requirements of the consumer industries related to pyro-and hydro-metallurgical reduction to metals, cement, glass, fertilizer etc.

The increasingly difficult professional target is aimed at *total* and *most economic* recoveries, and also eco-friendliness and recycling (a tall order!) of the waste, such as fly ash, tailing, slag, inked paper, metal scrap, bacteria-systems, sewage, waste water etc.

Mineral engineering is a complex multi-disciplinary subject needing technical inputs from, and serving in return, some of the broad disciplines such as geology, mining, chemical engineering, material science, metallurgy, ceramics, fertilizer S & T, environmental S & T etc. This calls for a very special educational and R & D infrastructure.

The infrastructure that is required for the mineral engineering profession to serve India has been only partly ensured. Indian Institute of Mineral Engineers (IIME) founded

in 1968 is hardly on its legs. The IIT'S and some Metallurgy/ Chemical Engineering/Mining Departments in the country may be teaching the subject of mineral engineering, but remain oblivious to the complex needs of the profession. Indian School of Mines, Dhanbad is at present the only institution in the country offering specific programmes in this area.

Above all, we urgently need a super-structure for frontier-line education, research and development in the area of mineral engineering : a NMERTI, National Mineral Engineering Research & Training Institute, which would be an IIT and a National Laboratory combined. The present author of this article has been urging the Nation, untiringly for the last two decades, to institute at least one NMERTI, and adopt other measures, so that during the 21st century, mineral engineers and scientists may successfully develop and exploit the mineral resources for optimum national benefit.

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The Emergence of History of Medicine in India : Representations and Reconstruction

AMIT RANJAN BASU*

I

The study of history of medicine in India is probably as old as colonialism. Before that, I suspect, history was a part of the therapeutic discourses for the indigenous systems of medicine. To be more appropriate, I would say, those were not at all considered to be 'histories'. Healers relied on their resources of memories and written materials to chose the effective remedy and hardly considered any method started hundreds of years ago 'obsolete'! It was the colonial gaze that started looking at our practices and their desire to *know*, and to know it as objectively as possible, created the possibility of studying history of medicine. Travelogues from the time of Portuguese arrival till the last days of British colonialism bear ethnographies of various healing practices unknown (and bizarre) to them.[1] By middle of the nineteenth century we see many scholarly efforts producing comprehensive books on *Hindu* medicine. Most of these books including travel writings from eighteenth century, always mentioned the need of studying such histories. The *Hindu Medicine* project ofcourse, was comparative to show that how a great resource of knowledge has become obsolete today and how superior the Western medicine is with its unique universal rationality. Thus T. A. Wise wrote in 1845:

> Among the sacred records of Hindus there is a system of medicine, prepared at a very early period, that appears to form no part of the medical science, and is not supposed to have enlightened the other nations of the earth: a system for which Hindus claim an antiquity far beyond the period to which the history of the heroic age is supposed to extend.[2]

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However he noticed the decline of this practice after 'the neglect of the Hindu Medical Science on the part of the Muhammadan conquerors' and the 'diffusion of the European system of medicine operated as a discouragement to the study of the Sanskrit works'. He also explained that the expense of the drugs was high and the difficulty to procure the genuine stuff corroded the standard and led to 'the substitution of superstition and quackery'. This observation also makes it clear to the reader that the great Indian medical science is dying a natural death and now has become an object of history.[3]

Before I move further, I would like to raise the question: are we going to treat medical histories of India the way T. A. Wise read Ayurveda? Or say, are we going to produce histories of medicine in India that are mere facts of the past and has no consequence over our contemporary medical culture? Is it possible to 'totalize' a history, which comprehensively reveals the Truth? I think the question of History itself in general, including the representation of medical histories in South Asia has undergone certain radical transformation in the last two decades of the twentieth century. More than writing social histories it has raised crucial questions on the method and the discourse of power in colonial and postcolonial India.[4] All histories are various representations and reconstruction of the statements of the past seen through the questions of *the present* asked by the researchers. History may be seen initially as an endless, seamless web in which one event leads relentlessly to the next in causal succession, but I would prefer the position where historian sets about undermining this apparently smooth continuity by establishing thresholds, ruptures, mutations and transformations.

From this view point, I would speculate that history of medicine in India experienced a break in the early twentieth century when it served the colonial power strategically as the evidence of 'progress' that were brought by the rulers. This specialized way of *knowing* would work as an important tool of power based on previous orientalist and other experiences. The editorial of *Indian Medical Gazette* in January 1901 said:

> The commencement of the twentieth century is a fitting time for endeavouring to recall, in a brief sketch, the medical and sanitary progress of India during the past hundred

years. To do so even briefly may enable our readers to appreciate the difference between then and now.[5]

Starting with the bad sanitary condition of old Calcutta, he talked about organizing the medical service, foundation of medical schools, lunatic asylums, vaccination programmes, diseases of India, setting modern laboratories, and gave the specific instance of progress in Bombay. While describing the 'boundary line between the past and the present' he commented that:

> Sanitary Commissions were appointed for the Provinces, and the *great* struggle against disease was begun, an idea utterly foreign to the mind of the Native of India, who had been accustomed for centuries to look upon disease as a visitation of God, and as something that merely human efforts were powerless to combat...[p]erhaps one of the most remarkable advances of the past dozen or so years has been the *awakening* of the Government of India itself [emphasis mine].[6]

In the same issue and the consequent one of the journal, D. G. Crawford wrote 'Notes on the History of the Bengal Medical Service' and would publish his famous two volume work *History of the Indian Medical Service 1600-1913* after fourteen years.

While editing a recent book on *Race, Science and Medicine 1700-1960*, Waltraud Ernst has said that, there now exists a consensus that scientific racism, racial medicine and colonial rule were for a time closely linked, variously reinforced, and justified each other. Claims to racial superiority and Western scientific and medical hegemony are seen to have emerged alongside each other in the wake of the Enlightenment, culminating eventually not only in scientifically based racism in the nineteenth and racial medicine in the twentieth century, but also in the perceived enhancement and legitimization of colonial expansion by reference to medical and scientific progress.[7] Considering this, one has to read closely the colonial accounts of its hegemonic desire in writing a history of medicine that would place the colonized as of inferior quality both from their cultural viewpoints and their practice of modern medicine. As pointed out by Ernst, the colonial discourse of history of medicine has strategically deployed discriminating categories of race, class, caste and gender to *naturalize* them as scientific

discourses. Not only that, for them Ayurveda and Unani becomes practices of the past which could not achieve its scientific advancements. A passage from the centenary volume of Calcutta Medical College could be an interesting reading in relation to this:

> Although remarkable advances were made by the ancient Indian physicians and surgeons who laid the foundations of medical science in this country, unfortunately, as in many other departments of science, the eastern savants became bound by tradition, with the result that instead of progressing, knowledge actually retrogressed in the subsequent ages. In both the systems mentioned [Ayurveda and Unani], instructions were given by practitioners and by lessons usually at the house of a preceptor but very little attempt was made either at systematic dissection or practical work ... When, however, the British came to India, the efficiency of both these systems were at a low ebb, no improvements having taken place and no important discoveries having been made since the ancient treatises were written ... The treatment of diseases was necessarily empirical. No corresponding development of these Sciences took place in India during the decades in the nineteenth century when remarkable progress was taking place in the Western World.[8]

However nationalistic responses were not scarce. Innumerable sources in English and vernacular are available that critically assessed the colonial claim. But with recent interventions from the subaltern studies and other contemporary scholars, we are informed that the project of nationalist historiography was collaborative, kind of a mimicry, that highlighted elite practices and attempted to erase the heterodox of subaltern healing cultures. Hence we find Dr. Girindranath Mukhopadhyaya was being awarded the prestigious Griffith Memorial Prize of Calcutta University for the encouragement of advanced study in science and letters twice in 1911 and 1913 to write a multivolume book *History of Indian Medicine.* And for Girindranath, it was only Ayurveda that featured as 'Indian' medicine![9] Let us have a look at the long hundred and seventy-two pages of introduction he wrote in the first volume. While criticizing the claim of William Jones, who thought there are

not many valuable truths in the eastern books on the science of medicine apart from its informational value to Europeans, and of Willoughby who wrote similar things even after hundred years, Girindranath wrote:

> This need cause no surprise, for the majority of medical men practicing in India are ignorant of Sanskrit language in which the ancient medical books are written and the exigencies of a lucrative practice have left them without inclination for the requisite study. But it must be acknowledged that it is not impossible for a surgeon or physician to become an active contributor ... The Sanskrit medical books still exist in manuscripts ... [o]nly a few important books have been edited and published; and there are numerous compositions, either treating of the whole system or of separate topics, that bear a character of more or less weight. One or two books only have been translated in English in recent times. So practically these works are still sealed books to the world, and the historians of medicine make no room for the study of Indian medicine in their works.[10]

Devoting pages after pages on bibliographical research of European and American works on history of medicine, Girindranath lamented that:

> [W]hile so much is being done in Europe and America, we are quite apathetic in India ... There is not a single chair of the history of medicine in the Indian Universities, nay, I am sorry to say, even in the English Universities. Far from learning the history of Indian Medicine, the graduates of the Calcutta Medical College scarcely know any history of the system that they practice.[11]

After defending quite elaborately why history of medicine should be studied he went on to argue the utility of the Hindu system of medicine, not mentioning ofcourse why the study of other existing systems will be excluded. He compared Ayurveda with the Greek system and showed similarities and gave an analysis of the Hindu system as an all encompassing medical discourse, which also has the knowledge of vaccination and venereal diseases. It is not very difficult to identify the nationalist desire that was working in Girindranath's history of medicine

to re-establish a Hindu medical science in modern India. So he provided the reader with his proposal of 'the various ways of making the study of history of medicine popular among the medical practitioners in India' and talked about three things: museums, exhibitions and a scientific library. It is interesting to note that he was adopting all the modern methods of study and classified his exhibits in twelve sections under Western scientific categories for attracting his target audience.

Girindranath's book is representative of a dominant genre where Hindu medicine became telescoped with the nationalist agenda and would direct the course of history of medicine in India. It would try to incorporate Ayurveda in the story of 'progress' that is proposed by the Western science and eliminate the 'obsolete' and 'irrational' contents from the discourse and every history of Indian medicine would present us with an evolutionary narrative from Ayurvedic antiquity to the modern medicine, coterminous with our nationalist history.

II

It is strange to note that despite the existence of Unani medicine for hundreds of years, no medical history was written on that till Dr. Mohammed Zubayr Siddiqi, a professor of Islamic Culture of Calcutta University published his *Studies in Arabic and Persian Medical Literature* in 1959! Writing the foreword for the volume, Dr. Bidhan Chandra Roy, Chief Minister of West Bengal commented:

> The contribution of the Arabic and Persian writers of the medieval period, to the development of medical science is immense. These masters of medicine made many important discoveries in the field of medical science. It is their achievements in this sphere that served as the foundation for its modern developments. Several European Orientalists and historians of science have dealt with them in their works. But so far they have touched only the fringe of the field. In this book Dr. Siddiqi has brought to light many facts which were so far generally unknown ... He has fully discussed the earliest Arabic medical compendium which contains a description not only of the Greek system of medicine but also of the Indian medicine on the basis of four of the important ancient Indian medical works.[12]

Siddiqi's book can be called the Islamic counterpart of Girindranath where, a well trained historian with similar nationalistic desire is trying to workout a factual narrative. However, there are obvious differences and the most striking of them is his rich discussion on the dialogue between Arabian and Indian (Hindu) systems of medicine and what shape Arabian medicine took in India. Another noticeable feature is that, compared to studies in Ayurveda, history of Islamic medicine or Unani in India is much less in number despite its existence for seven hundred years![13] In a painstaking bibliographical research on source materials on science and technology in medieval India Rahman et. al. provided a quantitative analysis of materials on medicine in Persian, Arabic and Sanskrit:

Documents on Medicine by Language and Century:[14]

Century	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	Undated	Total
Persian	1	3	4	5	7	4	21	18	120	102	133	124	110	652
Arabic	1	16	14	20	14	33	5	1	10	12	6	13	56	201
Sanskrit	11	6	29	26	38	31	50	36	61	122	80	47	3569	4106

Nevertheless the tradition of writing history of Indian medicine of the Girindranath genre continues and we find a recent 527 paged volume on *History of Medicine in India* where Siddha, Tibetan and Indo-Arab relations are covered in only forty pages.[15]

In postcolonial India, the governmental effort to establish departments for history of medicine started in 1956. The second Five Year Plan proposed to establish chairs of history of medicine in selected medical colleges. The letter said:

> Encouragement of the study of History of Medicine is specially important in this country, not only in the training of Physicians but also in reviving, assessing and reconstructing the indigenous systems of medicine. A great deal of effort is required to produce an accurate and complete history of these systems of medicine and to evaluate how far the basic principles contained in them could be utilized to advantage in the training of physicians.[16]

We all know that under Central Council for Research in Ayurveda & Siddha, Department of Indigenous Systems of Medicine & Health and Ministry of Health and Family Welfare,

the "Indian Institute of History of Medicine" still exists in Hyederabad and they publish *The Bulletin of the Indian Institute of History of Medicine.* But how much role it is playing to develop the study to a level where it draws a wider and respectful scholarly attention is doubtful.

When the scholarship of history of medicine in India in early postcolonial times produced big volumes of comprehensive, chronological and evolutionary narratives, it also produced an impressive list of source materials which were being seen for the first time.[17] One can not avoid here to notice that much of the histories of medicine in India were undertaken by the colonialists before 1947, which prompted the nationalists to represent their own histories of medicine as mentioned before. The nationalist trend continued and the strategy of history writing followed the linear, progressive course, revising the colonial agenda and identifying other 'obsolete' contents that has fallen out of development.

From nineteen eighties, I think a new genre of studies emerged which brought another break. As hinted before, these studies were influenced by the questions of method, issues of power, translating the science, and the question of culture in interpreting medical practices. Thomas Kuhn had already stirred up the scientific community with his concept of *paradigm shift*[18] and Michel Foucault's concept of *archaeology,* a concept that is different from history[19] generated departures from the previous position on history in the seventies. However, it was not before nineties we observe its impact on the South Asian studies.

The studies in the eighties predominantly scrutinized the colonial power through the public health models and also started examining other branches of medicine to understand the deployment of 'tools of empire' and social control of the colonized bodies. By doing this they opened up possibilities to move beyond, taking into account the ideological dimensions of science, technology and medicine. They raised the issue that, it was not a simple one-directional process of scientific and technological 'transfer', rather a complex process of cross-cultural interactions that have contextualized social, cultural and political dimensions. It influenced both, as argued in the works of Ashis Nandy, which appeared in the eighties and provided a different but powerful critique of the modern science and its association with power in the colonial and postcolonial world. Without

following a historical method, he innovatively constructed critical biographies of modern science in colonial and postcolonial India by, what he calls, the political psychology.[20] Not only the intentionality of medical education and various health strategies were explored, issues on different hierarchies of caste, gender, class and race started being examined in relation to health. Studies from colonial experiences of other countries provided an interesting scope to understand colonial medicine in its heterogeneity.

In the nineties, influence of Foucault was clear. In his *Colonizing the Body* David Arnold wrote:

> Anyone who sets out to try to write a history of the body is inevitably indebted to Michel Foucault, and anyone familiar with his seminal work will find influence of *Discipline and Punish, The Birth of the Clinic,* and *Power / Knowledge*...in these pages. But this book is not intended to be an imitative or uncritical reading of Foucault...[I]t is concerned with the creation of a state-centred system of scientific knowledge and power, rather than the more diffused and generalized forms of knowledge and power he described.[21]

When Arnold was more interested to examine the state power and resistance to it essentially, others were not so. Gyan Prakash's book *Another Reason* looked into science's cultural authority as the legitimating sign of rationality and progress.[22] In the first part of the book Prakash analyzed the historical feature of science's career in British India, describing how its close relationship with the state conditioned its authority in the realm of civil society. In the second part he used Foucault's concept of *governmentality*[23] to show that, colonial governmentality operated as the knowledge and discipline of the other. It was positioned as a body of practices to be applied upon an alien territory and population. But here too, colonial conditions compelled the art of governance to operate as a mode of translation. This becomes evident in the realm of modern medicine, which was introduced in response to the epidemics, and medicalized bodies became objects of struggle as the nationalists mounted a campaign to seize the body from its colonial disciplines. What stands out in the Indian case is how modern power has historically sought to overcome the limits imposed by its association with alien dominance, how the

territory forged by colonial techniques became the space of the Indian nation.[24]

Kalpagam also used the Foucauldian framework of power/ knowledge, his notion of *episteme* and *governmentality* to show how colonial governance produced the statistical knowledge ushering in a new social scientific discourse of 'progress', 'history', 'economy' and 'society'.[25] In a brilliant piece on colonial anthropology and Western hegemony, Talal Asad has said:

> Right through the modern imperial times and places, Western techniques for governing subjects have radically restructured the domain we now call society – a process that has recognized strategies of power accordingly. This process has been extensively written about (and not only by Foucault and his followers) in the context of modern European history, but far less so in the context of Europe's imperial territories. In fact the difference between the processes of transformation in the two contexts remains to be properly explored...Until we understand precisely how the social domain has been restructured (constituted), our accounts of the dynamic connections between power and knowledge during the colonial period will remain limited.[26]

We have now arrived at a situation where the study of history of medicine in India is a complex area that involved issues as serious as problems of methods of history, Western rationality, translation of concepts and of governmentality in a modernity specific to our culture. I have tried to argue that, the representations and reconstruction of the history of Indian medicine are many and it varied according to the time and space where production of knowledge is intricately linked with the deployment of power. To work in this domain we not only need to adopt interdisciplinary research methods but also raise questions on representation and reconstruction of healing cultures, which were hitherto relegated as subaltern practices full of superstition, bigotry and backwardness, read as 'folk' or 'tribal medicine.' The whole discourse of 'folk' medicine is problematic as it is continuously reproduced by an orientalist gaze.[27] Rather than writing totalizing and triumphalist histories of the modern medicine in India, I would be more interested to explore how our pasts of modern medical practices have implicated us in a perpetual 'lack'? I think it is crucial to

deconstruct such Eurocentric self-description and open up possibilities to reconstruct our strengths that lies in our hybridity and a heterodox of healing cultures.

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population. The state is governmentalized. Foucault wrote: "To govern a state will therefore mean to apply economy, to set up economy at the level of the entire state, which means exercising towards its inhabitants, and the wealth and behaviour of all, a form of surveillance and control as attentive as that of the head of the family over his household and his goods." See his "Governmentality," in Graham Burchell, Colin Gordon and Peter Miller eds, *The Foucault Effect: Studies in Governmentality*. Chicago: University of Chicago Press, 1991, pp. 87-104.

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Colonial Science

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Colonial science has been defined by George Basalla as the absence of scientific tradition in the colonised country, the arrival of western science and technology and the transformation of such traditional societies into modernity.[1] Daniel Headrick also holds similar opinion.[2] Foucault in his Order of Things explains the use of scientific knowledge for hegemony science and technology also constituted a tool of empire or imperialism.[3]

But it is well known that India had a long heritage of scientific knowledge as propounded by Bhaskaracharyya, Aryabhatta, Barahamihira, Bramhagupta, Kanada, Jaimini, Kapila, Nagarjuna, Charaka, Susruta, Patanjali and Dhanwantari etc. Nor was western science effectively introduced in India by the colonial government so as to cause a transformation of tradition into modernity. Colonial science was basically the employment of S and T for exploration of natural resources and extraction of the same for export to the mother country. [4] There was also an evangelical motive to civilize the colonised country and make it conform to Christian civilization. This in turn reinforced the empire.[5] A review of some of the principal scientific institutions in colonial India can bear out the truth.

We may begin this study with the first and foremost institution, the Asiatic Society founded by Sir William Jones in 1784 in Calcutta. Information about the land and people constituted an essential input for colonial administration. The government of Warren Hastings wanted to set up a society or a braintrust for gathering of all kinds of information for efficient administration of the colony and exploitation of its natural resources. William Jones, an Oxford graduate, well-versed in classical and oriental languages was specially recruited from England for the purpose of establishing such a society.[6] manifesto

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of the proposed Asiatic Society was to gather all kinds of information about the land and people in Asia in general. That included geography, topography, language, literature, history, religion, culture, manners and customs of the countries concerned. Under geography and geology, natural resources were tapped. It was a big project to discover the intellectual and natural properties of India and siphone them off to Europe to enrich European Countries. It is surprising to note that Jones did not mention our scientific heritage, though digging into the past for language, literature, religion and law. In fact, he remarks that in matters of science, Greece was in the driver's seat and India must take the back seat. This was a conspiratorial omission which was perpetuated by the ruling class throughout the 19th Century. The Asiatic Society was a white club till 1832. Indians were not permitted to be members of the Society. William Jones was in charge of scientific enquiries into geography, geology and botany. All he wrote on them was for colonial use and not for dissemination among the Indians. Even in matters of language, philology, literature, history, religion and law, the civilian member of the Asiatic Society were all indebted to the pandits of Nadia like Ramlochan Sharma, Radhanath Sharma and Jagannath Tarkapanchanan but their contribution was bypassed whereas the names of Jones, Wilkins, Gladwyn, Haihed, Colebrooke and Princep were overemphasized. Jones owed much to Ramlochan for his knowledge of Sanskrit and interpretation of texts like Sakuntala. So also Wilkins for his translation of Gita. Gladwyn depended on Jagannath for his rendering of the Hindu Law from Sanskrit texts of Jimutavahana and others. For linguistics and philology, there is the old text of Panini's Ashtadhyayi on which Jones must have depended. Prinsep owed much to Radhanath for reconstruction of Indian history and decipherment of Bramhi Script. But these subalterns have been sent into oblivion by historians.[8] It must not be forgotten that the discovery of India by the Asiatic Society was the European discovery and not Indian for enrichment at European culture. But sometimes, this manuscript-hunting and orientalism acted as unconscious tools of history for mutual benefit. India acted as the sounding board on which scientific theories of language, literature and history were tested. The construction and finesse of Sanskrit language was acknowledge and his appreciation of Sakuntala was that of a dilletante who advertised its merit to

Europeans for the embellishment of European Culture. We need not be overwhelmed by Jones' certificate of Sakuntala as a noble work of literature[9].

Material sciences were pursued as has already being observed for material gain. Jones was on the payroll of the Company's government as puisne judge of the Supreme Court to conduct enquires into the natural and cultural resources of India and published many articles on geography, geology and botany in Asiatic Researches[10] These were for the consumption of the ruling class and not for dissemination among the Indians.

This exploration was continued by many other western scholars of the Asiatic Society in later years.

Science and technology were never included in the curriculum of schools and colleges. Rammohan Roy had advocated for their introduction in a letter to Lord Amherst in 1823. But it fell on deaf ears. In 1835, Macaulay in his Minute on Education finally decreed that the government money would be spent on western liberal education of humanities with a sprinkling of science in English medium.[11] The colonial government was afraid that scientific education would equip the Indians with knowledge to stage an industrial revolution which would make them a manufacturing nation. They would no longer remain suppliers of raw material for English factories and buy their manufactured goods. Therefore, Indian tradition of science and technology was deliberately played down and it was not encouraged since the time of the Asiatic Society.

Let us now turn to the other scientific institutions, The Botanical Garden at Shibpur, Howrah was planned by Captain Kyd in early 1770s and it was finally launched around 1778. It was the nursery of not only Indian exotic plants but also many imported plants from abroad. The gardens were not just for the pursuit of scientific knowledge of Indian flora and their Linnean classification. The primary investigation was prompted by commercial cupidity. The value of Indian teak, sal, sissom, ebony and mahogony were investigated and accordingly they were murtured. Apart from that, some of the exotic commercial plants like tea, safflour, hemp, lac etc. were also put into the nursery for conditioning and final transplantation elsewhere. The Lloyd Botanical Garden was established in Darjeeling around 1796 and Botanical Survey was started about the same time. There was a flourishing business in exchange and sale of commercial

plants between Botanical Gardens of European colonies[12]. Richard Grove in his 'Green Imperialism' has tried to underplay green imperialism by stating that the botanical experiments in Botanical Gardens were guided more by the thirst for botanical knowledge than commercialism. Botanists like Wallich, Roxburgh and others produced marvellous treatises on Indian botany. They were also responsible for the Linnean classification of Indian flora.[13] .

The Botanical Survey on the other hand mapped out Indian botanical resources all over British possessions. Before the forest department was established in 1854, it was responsible for earmarking timber-bearing forests for conservation. Thus, teak, sal, sissom, ebony and mahogony woods were preserved for government exploitation. It supervised the supply of wood from the Indian forest The Indian Forest Department was established in connection with the construction of railways in India from 1854. The plunder of Indian forest started on a large scale to supply wooden sleepers for the railway It caused the single most important source of erosion of green cover in India. Indian wood was also used for the same purpose in England and other colonies. British capitalists came in large numbers to invest in forest based industries from 1880s. Chief industries among them were furniture and paper. Sawmills and paper mills came up in many places in India in the proximity of forest. Furniture included not only chairs and tables but also dance floors, stairs and doors. Wood was exported for the same purpose to the mother country and other colonies. Bamboo and grass were consumed for making paper pulps for paper mills. The British capitalists were especially privileged and protected under British rule. These industries were like monopolies where Indians were not admitted except as subcontractors [14]

Then there was the overwhelming urge for revenue maximisation from forest. Forest officials vied with each other to fulfil the government target, for there promotion and perquisites depended on it. It also led to rank corruption and carteling of forest officials, timber merchants and lorry contractors. Its bitter legacy was visible in post-independence India.[15]

Let us now turn from the secular to the sacred. The Serampore Missionaries had a big role to play in spreading scientific knowledge among the Indian people. The Baptist Missionary Society established the Serampore Mission in 1802.

Its presiding angels were the famous trio - Carey, Marshman and Ward. Carey was particularly responsible for translating the Bible into 32 regional languages including, of course, Bengali. Apart from this, he was also responsible for other Bengali works like Kathopakathan. Centering round them, there was a veritable Bengal Renaissance. Marshman was responsible for the publication of newspapers and periodicals like Samachar Darpan, Digdarshan and the Friend of India. Their Indian collaborators, Ramram Basu, Rajiblochan Mukhopadhyay and others also produced a number of literary works. They were also connected with the School Book Society and produced a number of textbooks in science and arts for them. For their own Serampore College and schools, they published similar textbooks. All these publications needed a press and supply of paper Carey built up a press with the help of Panchanan and Manohar Karmakar from Maldah. This was a letterpress which was later replaced by a rotary machine imported from England. A paper mill was also established to produce paper for the press. These two establishments in printing and paper technology caused a printing revolution in Bengal.

Carey was also known for his knowledge of botany He was a friend of Roxburgh, Superintendent of the Shibpur Botanical Gardens. They together had arranged and classified plants in the garden. They again had produced such famous works on Indian botany as 'Flora Indica'. Carey had also assisted botanists like Voigt in preparing a volume on flora of Calcutta and its suburbs. At Serampore, Carey had a private botanical garden of exotic plants from the East and the West and it has been remarked by Prof. Bruhl that most of Bengals fruits and flowers owe their origin to the seeds of Carey's garden carried by the birds and dropped elsewhere.

The educational curriculum at the Serampore College and schools had basic sciences like physics, chemistry, botany, physiology and mathematics. William Carey's son Felix had written a Bengali text of physiology and started an encyclopaedia, Vidyaharabali. John Mack, later principal of the college was a distinguished professor of chemistry from Edinburgh. He was the author of a text book of chemistry and its Bengali version. Besides, he had brought many instruments from Edinburgh with which he set up the first modern science laboratory in the east.

But whatever contributions they might have made in the field of science, their purpose was to preach Christianity and its miracles. Even in the school textbook, it was written that Christ was the source of all knowledge. They provided the evangelical support to the Empire by spreading Christian civilisation among the natives [16]

The last landmark in the field of science to be deact with here is the Calcutta Medical College which was founded in 1835. The colonial government decided in 1822 to set up the native medical institutions where Ayurvedic and Unani medicine were taught and practised. They were dismissed as unscientific quackery. All patronage was withdrawn from traditional medicine. The Calcutta Medical College was built on the land donated by Motilal Seal and its fund come from the Calcutta Lottery Committee to which many Indians contributed. In the management, apart from David Hare, Ram Kamal Sen and Dwarkanath Tagore figure prominently. An epoch-making event took place at the Medical College when Kaviraj Madhusudan Gupta was persuaded by Principal, Bramley to undertake the dissection of a deadbody to teach anatomy to students. The day was celebrated as the victory of western medicine over traditional medicine and end of superstition by the advent of science. The Calcutta Ayurvedists took it as their defeat and thought that Gupta was a betrayer Gangadhar Roy, the reigning kaviraj of Calcutta left the city in a huff for his ancestral home in Murshidabad.

Initially, only lower castes and classes came to study in the college for the job of compounder in the district dispensaries. The higher castes also could not make much headway. Pandit Madhusudan Gupta, despite his sensational role as a medical revolutionary did not rise beyond the post of sub-assistant surgeon with a pay of rupees 600/- per month at the fag end of his career But Dwarkanath Tagore sponsored the passage of three higher caste students to England for higher studies in medicine and surgery and one Surya Kumar Chakraborty was sponsored by Dr. Goodeve. They came back after passing their examinations to become professors and heads of department at the Medical College [17]

But the spread of western medicine was confined to Calcutta and its suburbs and a few district hospitals because of the shoestring budget provided by the military department under

which the Indian medical service operated. It was primarily of the white people, by the white people and for the white people. It did not penetrate the interior District dispensaries did not have a qualified doctor nor an adequate supply of medicine. Rural people had to queue up for a mile for a phial of quinine. As traditional medicine languished due to lack of official patronage, they were denied the benefit of both systems. Towards the end of the 19th century, a few more medical colleges were established apart from P. G. and C. M. C. Ayurvedic stalwarts like Gangaprasad Sen, Gananath Sen, Chandrakanta Sen, Jamini Bhusan Roy and Shyamadas Bachaspati also staged a comeback for Ayurveda while establishing one Ayurvedic college and writing medical treatises combining traditional and western medicine. Their demand for a bridge course at the university was ignored. Though Ayurveda was revived its degrees were not recognised and practice was discouraged. As a result, the issue was taken to the All India Ayurvedic Congress formed in 1920s to give battle to the government[18].

Thus colonial science attempted a half-hearted transformation of a traditional society destroying what it had without being able to supplant it by the blessings of the west.

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Renaissance : India and Europe

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Being multilinguistic, multinational India resembles Europe in many ways, where people of many origin and culture melted at the instance of various compulsions. The attack of Huns and Barbarians that resulted the fall of mighty Guptas and Romans almost at the same time paved the way for a new socio-economic system, i.e., feudalism. Though feudalism differs in many ways is these two parts of civilisation, there were some identities as the system caused the decay of material culture and the rise of religious bigotry. After a lapse of about one thousand years Europe took entirely a new turn, the driving force being renaissance, whereas India failed to have that.
H. G. Wells correctly said :

> From the time of Charlemagne onward the idea obsessed the political life of western Europe, while in the East the Greek half of the Roman power decayed and dwindled until at least nothing remained of it at all but the corrupt trading city of Constantinople and a few miles of territory about it. Politically the continent of Europe remained traditional and uncreative from the time of Charlemagne onward for a thousand years[1].

The question naturally arises, —why India could not have a renaissance-like situation during fifteenth, sixteenth centuries. Why India failed to produce another Copernicus, another Vaco da Gama, another Leonardo da Vinci, another Martin Luther? Let us examine the issue.

In Europe two central authorities, the Holy Roman Emperor and the Roman Catholic Church functioned since the days of Charlemagne, though contradictions and understandings among them also prevailed in the interest of both and manor-centred feudalism. Meanwhile the growth of many cities, particularly

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in the southern part of the continent (some of such trade-based cities were politically autonomous) and the successive battles of crusade resulted the strengthening of monarchies at the cost of landlords; another result of the crusade was the exodus of more serfs from the land and join as apprentice and journeymen in the trade guilds of the cities. The commerce was with the emporiums; like Swedish iron, Baltic lumber, English and Spanish wool, Flemish and Italian cloth, French wines, spices, silk, ivory, ornaments, and other artifacts from orient. Most of these towns had population of about 50,000 and also banking facilities.[2]

The political map of Europe in the two centuries under consideration did not differ very much from the present one. England, France, Spain, Portugal can be easily recognised. The central Europe bore the title Holy Roman Empire, which is approximately the modern Germany. Italy was also distinct with its glorious cities. The northern part of Norway, Sweden and Denmark was named as Denmark. To the east of Ottoman Empire of the Turks, Hungary and Poland-Luthuania exhibited close similarity of the present political version. Russia was there, obviously as it is today.

The struggles of some nations, particularly of England and France in achieving their identity were quite obvious. The growing nationalities out of amorphous European humanity or Christian masses and resulting gradual weakness of Holy Roman Empire was definitely a forward direction advancement of formation of nation based states.

Another feature of identified nationalities of Europe was the emergence of various languages. The Latin based languages French, Italian, Spanish and Portuguese along with Catalan (of north eastern Spain) and Rumanian, also the Teutonic languages, such as German, Dutch, Danish, Swedish, Norwegian came out successfully. Russian, Polish, Czech, Serb, Bulgar etc. were Salvic languages. English, the most important one is a hybrid, derived basically from Teutonic sources, but altered and enriched by large collections of Latin words and forms.

Politically, by the middle of fifteenth century, the Holy Roman Empire lost its grip over the entire Christian community and also European land holding. The Empire was not a nation state, nor was the Emperor an effective ruler. The Habsburgs were busy to maintain family possession of the imperial crown,

and was thus in theory more, but in practice less than a state. The growing nationalities and weakness of central authority of the Holy Roman Empire was the political feature at the time of renaissance.

But if we look at India of the same time we see a completely different scenario. Traditionally, Bengal, Gujarat and southern India enjoyed some autonomy whenever the Delhi-based central rulers get weakned. The Saids, Lodis, Babar, Humayun and Sher Shah who controlled Delhi during fifteenth and first half of sixteenth centuries could not establish empires covering the whole of India and as a result the south, east and west established their own kingdoms. The Ilyas Shahi and Hussain Shahi rulers helped Bengal in attaining prosperity. The Vijaynagaram kings in the southern India ruled the Deccan for many years, so also the rulers of Gujarat. The great Akbar and his successors could be able to embrace all these independent kingdoms within the Mughal empire. Thus, at the beginning of seventeenth century when we see the gradual decay of central authority of Holy Roman Empire and strengthening of the language-based nation states, in India the picture was entirely different. The Mughals embraced the whole of India, leaving very little outside its domain. The imperialist Mughal's well-knitted administration, military might, economic arrangement made influence over India, except one or two distant parts. For instance, a Sino-Indian group of people overran Assam, established the national kingdom of Ahom there, which endured throughout the Mughal period.[3]

The sovereign cities of Europe that played important role in the renaissance had no counterparts in India. Whatever important roles played by Surat, Maslipatanam, Satgaon, Hooghly, Chittagaon, Dacca, Burhanpur, Pippli there were some limitations. During Mughal age both inland and foreign trade expanded considerably, creating large internal market for goods and services. 'The peace and order established by Mughals in most parts of India, the uniformity in state regulations within the empire, the royal patronage to certain craft industries, the establishment of royal *Karkhanas* in the imperial capitals, and the maintenance of a large salaried class comprising soldiers, retainers and others led to the growth of market economy. Even the sultanate period prior to Mughal rule saw the flourishing economic activity particularly in port-cities. However, the

commercial structure of Indian economy largely depended on the direct agricultural exploitation by the way of cultivation of *khalisa* land, *ijara* land. On the otherhand the manors of Europe gradually weakened due to exodus of agricultural labourers either to royal army or city based small factories. It is well-known that such type of exodus began at the very start of crusade making kings stronger and feudal lords weaker. Again, the western part of Europe was traditionally poor in agricultural activities resulting more and more dependence of nation-based kings on commerce-earned revenues and also on earnings from the "new world" just discovered across Atlantic. It is also well-known that piracy and slave trading with the African blacks made a good contribution to the wealth of European countries of that time.

There were distinct features in Indian and European economy that had different prosperity for the coming days. Indian economy was mainly dependent on agricultural surplus. The effect of distribution of land and land revenues as designed by Todarmalla among the *mansabdars,* the military-aristocracy that rested largely upon agrarian surplus, tribute and war plunder were the principal sources of Mughal earnings. Most of the cultivable lands were under *ijara* system leaving only a fraction at the hand of Royal Government. During Akbar's reign, revenues from *Khalisa* territories stood only between 24-33% of the total revenue.[4] Mughals were fully dependent on *mansabdars,* both financially and militarily. Though Mughal consolidation in sixteenth, seventeenth centuries made India more forward marching, particularly comparing with the Holy Roman Empire, the gradual emergence of regional powers like Sikh, Maratha, Hyderabad, Bengal, Awadh in the closing years of Mughal dynasty made her picture more blurred and damped. Among the causes of such "federalism", the historians particularly stressed upon the practice of Mughal Royalty to distribute the land under *ijara* system more than under the *Khalisa* system.[5]

On the otherhand the nation-kingdoms of England, France, Spain, Portugal, Netherland (all in the western portion of Europe) could be able to consolidate themselves, particularly at the cost Habsburgs of Holy Roman Empire. They had well-connections with trade, commerce, piracy etc. As Charlton J. H. Haye told :

> All the Tudors of England (Henry VII to Elizabeth) asserted their supremacy in the sphere of industry and commerce. By a law of 1503, the craft guilds had been obliged to obtain the approval of royal officers of England or whatever new ordinances the guilds might wish to make. Elizabeth's reign was notable for laws regulating apprentinceships. In the case of commerce, Henry VII negotiated the *Intercurses Magnus* with the Duke of Burgundy to gain admittance for English goods into Netherlands, or chartered the "Merchant Adventures" to carry on trades of English woolen cloth or sent John Cobot to seek and Atlantic route to Asia. Elizabeth countenanced and abetted explores and pirateers and smugglers and slave trades in extending her country's maritime power at the expense of Spain.[6]

By the year of 1500 the Valois family could consolidate the French monarchy territorially and politically. The Bourbon family produced one of the greatest king of France, Louis XIV (1643-1715). Colbert, one of the Louis XIV's minister of reputation was essentially a financier and economist. France was in the midst of tremendous economic activities much before the era of Louis XIV. "Fairs like those of Champagne, in France on the trade route between the Rhone valley and the Low Countries, were going way the permanent markets in cities. In the north the Hanseatic League of cities on the German and Polish rivers, the North Sea, and the Baltic, was matching the activities of the Italian cities like Venice and Genoa. Occean-going vessels were passing Gibraltar on their way to and from the English Channel and the North Sea. The Alpine passes, the Rhine, the cities in the Netherlands and southern Germany were busy. Throughout Europe lesser towns were developing trade. Merchants became money-changers and bankers and dealt with in a variety of credit and investment devices. Shares were sold in joint-stock enterprises. Banks and merchants-turned-bankers accepted deposits and issued bills of exchange which facilitated transfer of funds."[7]

With the appearance of the protestant reformation certain changes in business ethics were obvious. John Calvin particularly accepted commerce, profit and interest as proper. The manner of life which he and his followers preached called for hard work, thrift and sobrity — just the kind of behaviour

which was suitable to a capitalist system. The reformation, the political fallout of reformation, the counter reformation including the Jesuit movements resulted a situation for greater freedom to profit-making as well as the gospel of hard work and austere saving. Merchants branched out into banking. The sixteenth century was the great age of family enterprices in finance.

Parallely if we look at India, we also see certain changes in religion, in trade and commerce and in socio-political scenario. The meeting of two religions (at the start of thirteenth century), particularly of Hinduism and Islam having divergent ideologies and beliefs produced antagonastic environment at first, but as the days passed off, conciliation and understandings developed. The *bhakti* and *sufi* movements averted the orthodox standpoint of their religions and devotees labelled as saints or mystics appeared. The origin of *bhakti* can be traced back to an earlier period, and the two great preachers, Jnandeva and Namadeva were regarded as precursors of the great movement. Similarly *suficism* had its past outside of India, however, it penetrated deep root in Indian soil also. Nizam-ud-din Auliya was one of the greatest sufis of the Chishti order in India and a mighty spiritual force, laid stress on the element of love as a mean of realisation of God. Thus love and devotion, submission to *guru* or *pir*, tolerance, unorthodox approach in religious functioning were main features of both *sufi* and *bhakti* movements. However, unlike the impact of reformation of Christianity, these movements were not able to make an impact in the political, economic and commercial life of India. While the protestants and catholics battled the political, economic and commercial life of India. While the protestants and catholics battled for supremacy, *suficists* and *vaishnavbites* maintained peace and harmony not only among themselves but also with their adversaries. Even Hindu kings did not attack the Muslim kings and *vice-versa* only because they were in opposition in religious faith but due to some other reasons, may be economic, political, military (strategic). *Sufi* and *bhakti* movements had nothing to do with commercial activities. Though a sizable number of traders followed the *vaishnaba dharma* and favoured it due to unorthodox approach and also as the traders were at a lower position in the caste heirarchy, *vaishnava dharma*, unlike calvinism and protestant creeds, never encouraged commerce and business. Instead, both the Hindu and Muslim kings made

some rules that ultimately discouraged commerce. For instance, the wealth of a rich trader was generally confiscated by sultans or kings after his death. Francois Bernier, a doctor-cum-traveller in India in seventeenth century first identified the pattern of land distribution, termed "Asiatic feudalism" in which the king or the state was the owner of all lands[8]. Marx Subsequently analysed the Asian mode of production. Some *pundits*, after study, concluded that the Asian variety of feudalism, bureaucracy discouraged the entrepreneurship among the habitants not only of India, but also Arabia, Persia, China. Just like China, a non-hereditary bureaucracy functioned in India which was not helpful for any sort of new venture. Joseph Needham in his colossal work on science and civilisation in China identified "mandarinates" (bureaucrats) who blocked the way of adventure as was found in Europe.

As said earlier both sultanate and Mughal establishments depended upon the agricultural surplus and as time passed the central authority ran the government with more and more provincial support. The weakness of the central government obstructed the building of a nation-state covering whole of India and ultimately this weakness infected the military power. Musket-wielding infantry, disciplined standing armies mobile artillery, new type of fortification techniques, naval improvements, the bulk provisioning of armies through private contractors were the principal features of military organisation of European states, whereas India and other oriental countries failed in this respect because these were capital intensive affairs. European governments were more inclined in strengthening the government machinery financially but Mughals and Sultans lagged behind. The subsequent defeats of Indian armies at the hand of English power in eighteenth and early nineteenth centuries have many reasons including the long negligence of Indian military. While important nation states were formed in Europe at the cost of Holy Roman Empire, the India provincial *subas* could not do so as there was always a balance of power between the central authority and *subas*. The Government at Delhi was not as weak as the Holy Roman Emperor.

There was another source of revenue earning, particularly for the Spaniards and Portuguese at first, and then English, Dutch, French etc. Gold, silver were shipped to Spain from the treasuries of native Americans. Slave trade from the littoral

states of west Africa also helped the Europeans in building capital for strengthening both the government-power and proto-capitalism. Indians avoided the overseas activities for many reasons including religious. An estimated 200 tons of gold and 18000 tons of silver were imported from Latin America to Spain between 1503 and 1660. The inflow of precious metals into Europe decreased after 1650. The price rise due to increase of supply of coins containing gold and silver slowed down by 1620s. But Europe's economy had been provided with a supply of metallic money that spurred greatly the progress of commercial revolution and of capitalism.[9]

As time progressed the slave trade was becoming highly profitable. It was estimated that between 1450 and 1500, about 150,000 Negro slaves were secured by the Portuguese.[10] Spaniards and other countries followed the Portuguese. They sent the black Africans to the New World for agricultural work, especially in cotton field, cane sugar field. The huge profit out of the trade helped the English, French, Dutch people. Another illegal overseas activity was the piracy. English pirates plundered the ships of Spaniards when it sailed for Europe. These happened at the direct encouragement from Queen Elizabeth.

Indians could not accumulate finance in the ways as done some European nations. However, commodities produced in India were of high value in the European markets, the trade balance was in favour of India and the European merchants had to pay bullion in exchange. Most of gold, silver collected by Indian merchants could not help them in trade and commerce but found place in the treasury of wealthy men. The gold, silver were arrested in ornaments jewellaries.

In the preachings of Hinduism, the voyage across the sea was discouraged. It was said that a person dare to cross a sea will loose his *dharma* and *jati*. Though Muslims had no such taboo, however, the sultans and the *badshahs* discouraged activities in sea. They even were not interested in developing navy. It is well-known that the Portuguese blocked the sea routes of the Mughal ship carrying pilgrims to Holy Mecca. Akbar himself consented to take *cartaz* (a passport for safe sea voyage) from the Portuguese for the imperial ships leaving the Gujarat coast every year for the Red Sea and Gulf.[11] Emperor Akbor who patiently listened from a travellor the discovery of the New

World across Atlantic did not express any curiosity though Mughals were well connected with the distant Ottoman Turk Empire at Constantinople. They were eager in building the empire over the lands of Asia, Europe, Africa but could not foresee the importance of navy in fulfilling the dream of the empire.[12] The Mughal ships were heavy and unlike Portuguese flotilla these were unsuitable in sea combat. Though the sailors of Gujarat and Bengal were renowned for their dexterity in naval warfare and they were also employed in Mughal fleets, but the activities of these fleets were mainly concentrated in defending the coast lines rather than adventure to deep seas. What gave Europeans the advantage was their success in adopting guns for use at sea, mounting cannon on shipboard and developing techniques for their effective manipulation in naval warfare.

Though Spain and Portugal could not maintain their supremacy over the sea for various reasons, their maritime knowledge were soon acquired by other European nations, such as England, Netherland, France. Portugal being trapped by the orthodox Catholics and inquisitions lost all the qualities of Prince Henry and his associates.[13] Oppression of inquisitions over the protestants and neo-converts reminds us of the fate of all-time famed Portuguese doctor Garcia da Orta in Gao. One of his sister was burnt at stake, Orta's dead body was exhumed after twelve years of his death and solemnly burnt in an *Auto de Fe* held at Goa. The downfall continued until Portugal lost its political freedom to Spain.

Spain also lost its supremacy of sixteenth century due to various reasons. The defeat of her Armadas at the hand of Britain, the gradual weakening of Holy Roman Emperor (of Habsburg family) made Spain marginalised among the European powers. The huge property of the Habsburgs under the Spanish branch and the Austrian branch slowly disintegrated into various states and monarchies. The glorious days of Holy Roman Emperor Charles-V (Charles I of Spain) and Philip II were lost. The great monarchs of England. France shaped the political, economic and cultural destiny of Europe.

While in Europe there was disintegration, divergence, dissociation, in India we see a reverse trend. The distant states during the Turko-Afgan rule though were successful to remain independent at the time of first two Mughal emperors, the great Akbar and his successors embraced them in the Mughal empire.

There was cohesion, adherence, association in India. The distinct centralized rule of about two hundred years created many problems some of which were discussed previously. Even when the Mughals were declining, the Bengal, Audh, Hyderabad, Carnataka nawabs, the Marathas, the Sikhs could not master their strength to the standard of a state compared to European counterparts. Their economies were traditional, their war-technologies were age-old. Only Tipoo Sultan of Carnataka tried to develop his navy at the Arabian sea, their artilleries were developed. The French, Portuguese and Dutch were the main consultants of Tipoo Sultan. Tipoo Sultan possessed a number of men of war and had about 10,000 men manning a variety of ships. On apprehension of British adventure he issued marine regulation in 1796 and ordered the immediate building of forty warships.[14] The defeat of Tipoo Sultan at the close of eighteenth century dropped the curtain over the history of pre-British India and there remain no political force in India that could challenge the British. The various political powers of the then India could not foresee the future of India under British domination.

The status of education, religion, culture also differed widely in two continents. It is true that education was religion-controlled, so also the culture and values. State supported the education financially though had little to do with the content of education. The monasteries, clergy controlled schools, *madrashas* and *tols* administered by holy men of both Muslim and Hindu religion functioned during the medieval period.

From the days of Charlemagne Europe took a shape of loose confederation under the title of Holy Roman Empire and the Christian authorities could controll the education and culture of all Christian population. The state's support of Christianity and the marginalisation of other minorities made it possible to develop a uniform monolithic educational pattern throughout Europe, particularly of Latin Christendom, Charlemagne himself supported Christian monasteries to set up schools and helped to translate and copy the books of importance. Charlemagne also stressed upon the secular education of his subjects. He opened a school in his palace for family members where all-time famed Alcuin and Paul de Decon were engaged in teaching.

Most of clergies were educated, disciplined and followed St. Benedict's guidelines on daily life. George Sarton in his *History of Science* clearly stated :

During the sixth, seventh, eighth and ninth centuries the benedictine monasteries were the chief civilizing agencies in western Europe.

The light of education that was kindled at the time of Carolingian renaissance continued to illuminate till the Italian renaissance took the charge. The continuation of the education system in churches and then the establishment of universities were responsible for the inquisitiveness of a section of population. Astronomy, medicine, geometry, literature, philosophy, Christianity, law, were taught in the universities. Famous universities like Salerno, Bologna, Paris, Oxford Universities were founded much earlier. Salerno and Bologna Universities came up in eleventh century, Paris, Oxford were established in twelfth century. Thus within a time span of about three hundred years twenty universities were organised in Latin Europe. Italy, France, Spain, Portugal, England were in the forefront in setting-up universities. The Arabian scholars and the Arabian translations of Greek books helped the Latin scholars to have a new look to their ancient glory. They translated Aristotle, Plato, Pythagorus, Euclid, Galen in Latin. The philosophy and science of these Greek *pundits* were slowly absorbed by the Christian world and became the core of the Christian beliefs. The rich heritage of Greek, Greco-Roman, Alexandrian civilisation was adopted by the Christian world. The civilisation of middle-east including Arabia, Sumeria, Egypt, Persia was also proudly recalled by them.

The cities vibrant with commercial activities were also proud of having universities. A good percentage of city-population were students. The tremendous rise of the number of students was a typical feature of medieval Europe. Of the 50,000 population of Paris. 7000 were students. Students moved from one corner of Europe to another corner in search of good teacher, enlightened association. There was a common language for education, and that was Latin. Any educational activities in a language other than Latin could not be thought of. Use of Italian, English, French, German, Spanish languages in writing books, in discourse among the *pundits* began much later. Environment in the monasteries, churches, universities were helpful for intellectual development, though orthodox and conservative ideas dominated the atmosphere. It is true that almost all

stalwarts responsible for intellectual advancement of Europe were connected with the church-based activities. The universities also catalysed the spirit of enquiry, thinking among their alumni.

Roger Bacon—a product of Oxford University and his contact with Pope Clement IV proved Bacon's intellectual elitism. Copernicus, Kepler, Galileo were connected with religion-controlled institutious at one time of their life. The discoveries or development of each and every branch of science, be it in astronomy, mathematics, physics, chemistry, medicine, anatomy, geography were made by those who were the product of these European universities. They were intellectually and academically superb, particularly when compared with fellow citizen and non-western population. A Euro-centric scientific achievements were found from sixteenth centuries onwards. Europe could be successful by fully utilising the economic, political consolidation, and also by employing her intellectual resources. She had not lost her intellects even when renaissance was far away. The so-called scholastic age laid the foundation of coming renaissance.

India during her medieval period saw an entirely different situation as institutions of learning, such as Nalanda University was completely destroyed in thirteenth century resulting delinking with the past. The Guptas, Harshabardhana and the Palas once supported Nalanda University to attain the status of an excellent institution which could draw students from distant parts of India and abroad. It is pity that all ancient universities of India, such as Nalanda, Vikramsila, Balavi, Odantapuri, Jagaddal could not survive during Turko-Afgan and Mughal period. Even the famous Hindu kingdoms of Vijayanagara, the Gajapati dynasty of Orissia, Ahom dynasties of Assam and other small Hindu kingdoms could not establish institutions of higher learning comparable to European universities. The Muslim sultans and *badshahs* were not interested in setting up universities of higher study. Whatever educational activities remain, all were with limited number of students, teachers and establishment. The *tols, patsala, madrasas* and *maktabs* were religion-oriented, scholar centred, sometimes supported by the state. The students learnt literature, grammar, logic, astrology, elementary mathematics, holy books, philosophy. Practical arts, such as medicine, engineering were taught in entirely different establishments, i.e., in the houses of *vaids, hakims,* in *karkhanas.*

The intellectual exercise was not comparable with the European universities especially in astronomy, mathematics, medicine, engineering, science. Thus another Copernicus, Galileo, Kepler. Newton, Halley, Hook, da Vinci, Harvey, Vesalius, Paracelsus, Agricola, Euler, Descartes who could break the age-old stagnation and finally emancipate the modern science, could not born in India. The educational establishments, be it either Hindu or Islamic at Kashi (Beneras), Navadwip, Kanchi, Jaunpore, Lahore were not fit to disseminate and to cultivate modern science. The *pundits* and the *moulavis* were busy in studying religious scriptures and other related topics. Science and practical arts were considered alien and unsuitable for persuation. The elites in the education were more interested in logic, philosophy, grammar, literature.

The ideological drives in the social, religious area were responsible for such state of affairs. First of all, the majority population, i.e., the Hindus were divided in many castes. Except the Brahmin and other upper castes, the remaining population were not educated. Those who were responsible for manual work had no right to be educated. The educated community looked down the labourers and so also the labour. Science, being closely related with practical art, experiment, manual work was also not respected by Brahmins and upper classes. Development of science in India in the medieval period was difficult for two reasons. One, due to disrespect from educated class and another due to illiteracy among the artisans, technicians. Most of the craft-works were caste-based and the artisans were at lower position of social ladder. The grand division of intellect and labour made good harm to both. The intellectuals were traditional, theoretical, not aware of practical difficulties of material world. On the other hand the artisans were illiterate, copy-master, could not develop their skill, neither they could solve the problems of their works due to lack of education. Again, the Brahmins and almost all the Hindus had scanty respect to the material world for they thought that this world or matter is *maya* or non-existent. The teachings of great Hindu Brahmin Sri Sankaracharya of eighth century introduced the *mayabadi* philosophy and by the influence of this philosophy people in general were not interested in developing the material life, so also science and technology. Hindus in general had little respect to trade and

commerce, the particular caste who were engaged in commercial activity were not at higher position in social heriarchy. Similarly the Muslims avoided commerce for some other reasons, particularly for a religious taboo on earning interest. They left it to Hindus, especially *bania* community.

The attitude towards nature was another area of difference between Europeans and Asians (Indians). This problem was elaborately discussed by J. Needham in many of his essays on history of Chinese science and civilisation. The Aryans during Rig Vedic period were believer in *rta*. Vedic *rta* was a conception connecting natural elements (cosmic world) with the constituent principles of body, i.e., unity of man and nature. *Rta* means the natural movements of sun, stars, moon, the cycle of seasons, formation of cloud out of water vapour, then the precipitation and other various natural phenomena. It was considered by the Vedic people as holy, true.[15] The conception of *rta* from Indo-Iranian period changed considerably in Yajur Vedic time. During Yajur Vedic times, instead of developing *rta* into the view of the laws of nature in the later scientific sense, the Vedic *rta* met an abrupt end in the vedic tradition. In the later period universe and man were thought to be manifestations of one and same eternal spirit. The philosophy of eternal spirit when carried to its logical culmination—as is done in *Advaita Vedanta*—leaves the universe including man as *maya*. *Vedanta* never tried to find out the laws of nature—the essence of science. However, some other sections of Hinduism though tried to explain the nature in other ways, the dominant *mayabad* shaped the minds of Hindus.

One of the oldest notion of western civilization was that just as earthly imperial law-givers enacted codes of positive laws to be obeyed by men, so also the celestial and supreme rational Creator Diety had laid down a series of laws which must be obeyed by minerals, crystals, plants, animals and the stars in their cosmos. The idea can be routed back to ancient Sumerian days. The sun-god Marduk is pictured as the law-giver to the stars.[16] The conception of universal law immanent in the world including non-human nature as much as man was found among the stoics. Romans were strongly followers of stoic philosophy, so also medieval and modern Europeans. Stoic philosophy stresses upon the willpower, work of man and it is more inclined towards materialism. The belief in the laws of nature and the

tradition of enquiry in Europe for laws of nature helped to develop science and scientific mind.

Italian renaissance stands as a watershed in the European history. The post-renaissance period saw the rapid development of modern science and technology. As the speed of progress get acclerated it advances further in a cumulative way. The difference between Europe and India in nineteenth and early twentieth century was so marked that none can believe that at one time these civilisations were comparable. After her independence Europe became a role-model to India and India tried to develop her people and country by following the developmental model of Europe. And there lies the success of Europe.

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Pioneers of Physics Research in India

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Modem physics witnessed resurgence in the last quarter of the nineteenth century. A large number of scattered, disorganized experimental observations of a very random nature were at the disposal of physicists and mathematicians who needed a breakthrough. The concerted effort of theoretical physicists led to an order and the knowledge became more effectively integrated. After Blamer's discovery of his simple but great analytical formula and Planck's formulation of his hypothesis physics entered the world of quantum era. During the period of British colonial rule Indian intellectuals made great advances in the field of cultural development. Indian science took an active part in this period of renaissance. Indian scientists were at par with their counterparts in Europe in the first three decades of the twentieth century that shook physics.

An outcome of Wood's educational dispatch the University of Calcutta, established in 1857, was merely an affiliating university with the onerous task of conducting examinations of students studying in different colleges spread over a large area. Along with teaching research work was mainly confined in Presidency College. Research in modem physics started under the leadership of Sir Jagadish Chandra Bose.

J.C. Bose initiated his pioneering research activity on wireless communication, which is the keyword of present day communication and information technology. It is not known to many people in India that Bose first developed the source of millimeter wave region. Bose was at least half a century ahead of his time. He was the first person to attempt communication using electromagnetic waves in the radio wave, microwave and millimeter wave. In 1887 German Physicist Hertz developed an instrument for generation of electromagnetic wave that was

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theoretically formulated by Maxwell in the middle of the nineteenth century. Visible light is also electromagnetic wave covering a limited range of wavelength. But the electromagnetic wave of Maxwell covers a very wide range of wavelength and has the same property of light wave. It is fundamentally different from the sound wave that propagates through a medium like air. As the light waves of different wavelength produce different senses of colour to our eye, the electromagnetic waves beyond the visible region have large difference in the energy and have different impact on the medium on which it is incident. But the basic properties of light like rectilinear propagation, reflection, refraction etc. remain the same in the entire range of electromagnetic wave extending from gamma rays of very small wavelength to the radio waves of very large wavelength. The waves generated by Hertz's instrument produced waves in the radio wave region having wavelength of the order of a few meters. So some properties of light could not be verified with the instrument of Hertz. In the mean time Hertz died. Bose made considerable improvement of the instrument to generate waves with wavelength of the order of a millimeter. He also developed an instrument based on a crystal called galena for sensing this wave. He could prove that the electromagnetic wave generated had all the properties of visible light. This was a great breakthrough as it established Maxwell's electromagnetic theory on experimental basis. His remarkable achievement in Physics was to demonstrate that electromagnetic wave could penetrate the walls of a room and can reach a sensor placed in the next room. In 1894 he performed an experiment when the waves started from the room of Acharya P. C. Ray and penetrated the walls of the closed room to the room of Professor Peddler. This was the first success of wireless telegraphy. The public demonstration of the same experiment was organized in 1895 at Town Hall in presence of the then Governor of Bengal. It was given wide publicity by the press. It appeared in the book "Hetzian waves and wireless telegraphy" by Poincare and also in the Proceedings of the Royal Society in the period 1895-1900. The invention was found in the patents issued in Great Britain and in America. Thus Bose's public demonstration of wireless communication was before that of Marconi who succeeded in transmitting the radio wave across the Atlantic.

During the first three decades of the last century Physics

research was centered in a few European institutes and laboratories under the leadership of eminent physicists. Science teaching and research was initiated in the University of Calcutta by the effort of the visionary Vice Chancellor Sir Asutosh Mookerjee. In the newly established Science College he invited C. V. Raman, an officer in the Accountant General's office in Calcutta to join the university as the first Palit Professor of Physics. Sir Asutosh also invited two young mathematics postgraduates of the University, Meghnad Saha and Satyendranath Bose to join the physics department as Lecturers. These were landmark decisions in the history of science and of the university. Raman found more time to concentrate on his experimental work that he was carrying on at the Indian Association for the Cultivation of Science established by Dr. Mahendralal Sircar. Raman was a physicist with great acumen for experimental work. His aim was to obtain an effect with visible light similar to the Compton effect discovered with X-rays. Compton effect showed that when X-rays are passed through a crystal there are certain changes in the properties of the radiation and these changes carry information about the nature of the crystal. Raman did not have any sophisticated instrument. He designed and developed a spectrograph with a glass prism that he could collect through one of his relations in the United States. Along with his student and coworker K.S. Krishnan Raman performed an experiment on benzene with visible radiation. It showed new weak radiations, which were shifted from the frequency of the incident radiation. This shift depended on the property of the molecule. The result was announced in 1928 and it fetched him Noble Prize in Physics in 1930. The effect was theoretically predicted by a German Physicist Smekal and very soon after the discovery of Raman two Russian scientists also observed a similar effect. C. V. Raman could achieve it with a simple indigenous instrument. Now the world knows that this effect has great impact not only in Physics but also in the entire domain of science extending from quantum optics and chemistry to biology.

In 1900 Max Planck formulated his quantum theory, which states that energy is released in the form of quanta rather than in a continuous manner. He introduced the formula E =hv. Satyendranath Bose studied with great interest Planck's law of distribution of energy radiated by a black body. The derivation

of the law was based on ad-hoc assumptions that Bose did not like. In 1924 Bose derived Planck's law by introducing a new statistical distribution of photons and communicated the paper entitled 'Planck's law and light quantum hypothesis' to Einstein and sought his opinion. Einstein immediately recognized the significance of Bose's new proposal and sent it for publication in the German journal Zitschrift fur Physik. Einstein added a note with the paper which is quoted as follows.

In my opinion Bose's derivation of the Planck formula is an important development. The method considered here yields also the quantum theory of ideal gases which I shall discuss elsewhere".

Bose's discovery was that particles like photon, a quantum of light, can occupy the same energy state and there is no restriction on the number of such particles occupying one state. This is in sharp contrast to the electrons, protons or neutrons that form the basic building blocks of matter. These particles obey Pauli Principle and follow a different statistics formulated by Fermi. Einstein published a paper in 1925, as he proposed in his note with Bose's paper, and showed that the statistics formulated by Bose is applicable not only to photons but also to a certain class of material particles that consist of even number of electrons and nucleons. This divided all the fundamental particles in the universe into two groups that obey either Fermi statistics or Bose statistics. The latter group of particles is known as Bosons and the others are known as Fermions. The fundamental difference between the two groups is that the Fermions are loners; they do not allow more than one particle to occupy the same energy state. Bosons are somewhat gregarious; there is no limit to the number of particles in the same energy state. Hence half of the universe has to follow Bose statistics. Einstein's 1925 paper also showed that if Bosons are cooled to very low temperature then it is possible that they will all come down to the lowest energy state and this will produce a new kind of condensed phase, whish was later called Bose-Einstein Condensate. Although Einstein proposed it in 1925 immediately after the publication of Bose's paper it took seventy years for the experimental physicists to realize BEC in the laboratory. This new phase has generated major interest among experimental and theoretical physicists, as the condensate is a dilute gas of atomic particles forming a mesoscopic system of

coherent atoms. Thus Bose's pioneering discovery has led to many fundamental concepts and revolutionized physics. It is a pity that the work did not receive due recognition and he was never awarded Nobel Prize although more than ten work based on his statistics received the award.

Meghnad Saha, a contemporary and classmate of Bose, initially devoted his research activity in thermodynamics. He worked on equation of state of real gases. He derived the famous Saha Ionization Equation. From this equation if the ionization energy of a substance at a certain temperature and pressure is known then the degree of ionization can be determined. Saha applied it for interpretation of solar spectrum. According to Saha's own statement the idea of working on ionization theory came to him when he was giving a course on thermodynamics and spectroscopy for postgraduate students at the University of Calcutta. He was not satisfied with the existing theory of ionization. So he was inspired to formulate his equation. It became the governing equation for stellar dynamics and astrophysics. Saha's notable contribution was establishing science research facilities or augmenting such facilities in different parts of the country. He established the Institute of Nuclear Physics at Calcutta University. It later became known after his name. Saha played an active role to revitalize research activity at the Indian Association for the Cultivation of Science. He initiated teaching and research activity on Nuclear Physics at Calcutta University; this was the first effort in any university in India. He had a leading role in fabrication of cyclotron and electron microscope at the university. Under his inspiration and advice teaching and research in biophysics was initiated at Calcutta. Thus Saha was not only a physicist of great caliber, but he also had a leading role in establishing institutes and initiating research in the upcoming fields of science.

Professor Sisir Kumar Mitra did pioneering research in the field of upper atmosphere and radiophysics. He was immensely influenced, by the discovery of generation of electromagnetic wave and its receiver by J.C. Bose. Mitra started working on ionosphere that reflects the radiowaves in the atmosphere. He established an ionosphere field station at Haringhata under the University of Calcutta.

An important feature of science research in the first half of

the last century was that it was centered on certain individuals. The scientific discoveries were mainly the outcome of the intellectual effort of scientists. It was not dependent on big budget and huge machinery or largescale instruments. In theoretical work all that was necessary was a pencil, a paper and a brain. This situation continued till the Second World War when Big Science replaced science based on individual efforts. After the war all scientific efforts were directed towards the development of new technology and production of consumable materials. Scientific activities were concentrated in the western world. In course of time developing countries like India lagged far behind in scientific activities. In India the government wanted to establish well-equipped research institutes and founded Atomic Energy Commission for research on nuclear science. No attention was given to science research in the universities. H. J. Bhabha formulated most of the science policies of independent India. Bhabha did pioneering research on cosmic rays at England. His idea was to develop the country as an industrialized nation. In the process he ignored the social situation in India. This idea was contrary to *Saha's* philosophy. The Prime Minister Nehru tilted to Bhabha's ideas. Gradually the centre of physics research shifted to Bombay from Calcutta. Science research became more bureaucratic in nature. Although there has been many excellent work of high international standard by Indian physicists, the country did not present any path breaking fundamental discovery to the world community in the last fifty years. Because of poor funding and infrastructure the university teaching suffered and the country could not produce brilliant students.

The recent Science and Technology policy admits that the country could not produce highly trained scientific manpower over the last decades. Even the oft-quoted claim that the country has the third largest manpower in science technology seems to be an exaggeration. At least this is not reflected in the quality and nature of our industrial products. There is also problem for recruitment of scientists in many institutions in India. Since this problem has been recognized by the science planners of the country it can be hoped that the situation will change in the near future and some more directed emphasis will be given to manpower development in science in the universities.

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History of Science Museums : An Indian Perspective

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According to Martine Barrere of the well-known French magazine, *The World Scientist,* the all-pervading scientific temper in India which figures in political speeches, in the newspapers and is found in the countryside as well as in the cities where research institutes abound, is more powerful than the off-repeated stereotypes of poverty, overpopulation, drought, monsoon, pomp and cultural sophistication. In India, perhaps more than anywhere else, considering the immensity of the contrasts, science cannot be considered an abstract object, unrelated to everyday life.

Not only the French science magazine, but the most venerable of all the mighty Encyclopedia Britannica has acknowledged the growing science museum movement in India. In the 15th edition of the Britannica the museum section mentions *"The museum has an important role in awakening the creative talent latent in each of us through spectacular exhibits and activities. Birla Industrial and Technological Museum finds its place next to Polytechnique Museum of Moscow". It also mentions the "BITM's pioneering role in extending museums' service beyond the confines of the walls".*

History of Science Museum in the world is almost 150 years old. According to the record the first science museum was set up at South Kensington in United Kingdom. In the year 1851 the great exhibition was opened in the Hyde Park on the initiative role of his highness Prince Albert and in 1856 collection of the exhibition was removed to South Kensington. Thus the South Kensington Museum was born. However in India the first Science/Natural History museum was set up at Nagpur during 1864. It was called "Central Museum". It had collections of

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Geology, Zoology, Ethnology and Anthropology etc. Subsequently During 1874 a museum was also set up in Kerala at Ernakulam with collections of Zoology and Botany at Maharaja College. The first industrial museum was founded in 1888 at Pune "Lord Reay Maharaja Industrial Museum". There were also discrete actions that took place at different parts of India without any connection between them. However a concerted science museum movement emerged only after independence when science and technology were given an important role in the First Five-Year Plan in 1952.

It was only in the middle of 1950s, sometime around 1955, that two very small nuclei were formed in India. One was 'National Physical Laboratory' in Delhi and the other one at 'Birla Institute of Technology and Science' at Pilani. Both these museums started with considerable promise and enthusiasm but after a few years for whatever reasons, the authorities of the National Physical Laboratory decided to close down the museum in Delhi. The 'Birla Museum' at Pilani continued to flourish and now it has taken a good shape. These two are the first instances of science museum movement in our country. Shortly thereafter, in 1956 the Government of India decided to set up a large Industrial and Technological Museum at Calcutta. The Birla Industrial and Technological Museum was subsequently opened to public in 1959. Later on in 1965 another Museum, Visvesvaraya Industrial and Technological Museum at Bangalore was thrown open to public. Both Birla Industrial and Technological Museum and Visvesvaraya Industrial and Technological Museum was managed and administered by Council of Scientific and Industrial Research, Govt. of India. These two along with the Birla Musuem, Pilani and Community Science Centre at Ahmedabad have done very useful service in the sphere of Public Understanding of Science particularly in the area of informal science education. These two museums i.e. BITM Kolkata and VITM Bangalore started becoming very popular not only amongst the school but also amongst the people in the state. More and more requests started pouring in from other states for establishment of such science oriented museums in the state. Accordingly Planning Commission did set up a Task Force during 1973 to examine the possibilities, prospects and need of developing science museums in line with National priorities. The Task Force after detail study suggested that need for development of such science museums exists and it also

mentioned in the report that this would help in creating scientific temper amongst the public. It also mentioned that a central organisation is essential to plan and implement schemes for future science museums. The Task Force mentioned that the science museums in the country should be set up in a three-tier mode. They may be called Type 'A', Type 'B' and Type 'C' museums. The primary facilities which would be created in Type 'A' museums would be designing, development and fabrication of exhibits for museums. It would have a full-fledged workshop along with a small R & D unit for conceptual development of exhibits and activities for future. Such museums they proposed would be set up in metropolitan big cities like Kolkata, Delhi, Bangalore, Mumbai etc. Type 'B' museums would be set up in state capitals. Such museums would have limited exhibit fabrication facilities alongwith all infrastructural support for maintenance of exhibits in the centre. Type 'C' museums would be placed in districts, particularly in less developed district to start with. They would have only facilities for maintenance of exhibits. However, all the museums should have infrastructure to execute educational activities for popularizations of science amongst the people. Such activities should be both inside the museums as well as outside (outreach activities). The report also quantified the number of museums under each of above categories i.e. A, B or C. However, the recommendation also mentioned that more museums could be set up in the country provided fund is available from other organisations either Private Industries or Sate Government itself.

According to the recommendation of the above committee an autonomous body "National Council of Science Museums" was formed on 3rd April, 1978 with the mandate of planning and administer science museums in India. Initially NCSM was attached to Ministry of Education and subsequently transferred to Dept. of Culture in Ministry of HRD and presently operating under Ministry of Culture and Dept. of Tourism. Subsequently a rapid growth in development of science museums all over the country was noticed. It may be recalled that prior to formation of NCSM there were only 3 science museums operating in the country which increased to 28 by the turn of the century. With the formation of NCSM another interesting thing was noticed. Very many new activities and programmes were slowly developing with the sole objective of "Popularising Science"

amongst the people and developed a scientific temper and understanding of science primarily through Hands-On Experimentation. Another noticeable thing observed was that the fixed exhibits in the galleries slowly changed from 'Push Button' type to 'Interactive' leading to experience based exhibits. Mobile Science Exhibition Unit which started earlier got a tremendous boost and not only the number of such Mobile Bus increased from 4 to 23 in a reasonably short time but also increased and attracted many more visitors to such Mobile Exhibition drastically. Mobile Science units was started with an aim of reaching nooks and corners of the country particularly in rural places of the country so that Science can be brought to the people who cannot afford to visit museums situated either at District Head Quarters or in State Capitals. With the Philosophy "Understanding Science By Doing" Science Fair though started prior to 1978, increased drastically after 1978 and slowly such Fairs started operating in three levels i.e. Block to District, District to State and State to Interstate. Thousands of students from hundreds of schools participate in such Science Fairs where creative scientific models are built by the students and displayed in the competition for explaining science to the people. Many other programmes, like Students' Science Seminar, Travelling Exhibition, Astronomy Programmes, Computer activities etc. to name a few to popularize science amongst not only the students but also common people started. Students' Science Seminar for example is another activity in which thousands of students, after extensively preparing themselves 'on the topic' delivers 6/7 minutes Extempore talk, before a sizable number of people which includes students, through charts and posters prepared by themselves. One survey taken sometime shows back few thousand students deliberates on a single topic and few lakhs of people including students listens to it having facility for two way communication. Such a big programme involving so many people is not conducted anywhere in the world for popularization of science.

NCSM subsequently undertook Mega operations like a huge exhibition on the topic "Dinosaurs Alive" which toured various parts of the country and was able to educate people about the Evolution of Dinosaurs but specially deals with the scientific reason "Why such huge robust animal vanished from the surface of the planet in a reasonable shorter period of time?"

Under experience-based learning, the concept of Mega Science Centres, was given by NCSM and the first 'Science City' was thrown open to public in Kolkata during 1996. Few Million of people had visited the place subsequently and enjoyed the "Fun of Science". Presently many other states are actively in the process of setting up such mega Science Centres in their own states to bring wonders of science to the people in consultation with NCSM.

Museum Professionals all over the globe including India is debating on possibilities of 'Virtual Museums' i.e. Museums on the 'Web' which could be visited sitting at home. Those who are advocating for it are having a strong case in favour. They argue that in today's world people have very little time to spare. In such a scenario if Virtual Museums exist one can draw lot of benefit from it by spending less time and money but the debate is 'ON'. However in such a scenario what the visitors would be missing certainly is the 'Joy of touching a 3 dimensional object'. This experience is no mean. NCSM is also actively participating in the 'movement'. Work is at hand for creating in the first instance 'Virtual Laboratories' on various subjects like Physics, Chemistry and Bioscience. In such Laboratories students would be able to enjoy the fun of conducting experiments all by themselves as many times as they need. In the case of Chemistry it will be extremely helpful at low cost. The rate at which Information Technology is stepping-in in our country it is felt at least *Virtual Laboratory* will be a reality in near future. It is believed it that happens it will certainly be a step forward in Popularization of Science & Service to School.

Medieval Science Technology
and
The birth of Industrial Revolution

SAMAR BAGCHI*

The setting

By the 3rd century A.D. Roman Empire was divided between the Western Roman Empire with capital at Rome and the Eastern Roman Empire with capital at Constantinople named after the Roman emperor Constantine. By the fourth century Christianity became the state religion. Western Roman empire decayed by slavery had collapsed by the fifth century A.D. due to attacks by Goths, Vandals, Franks and latter by Huns from the East. Europe entered into a so-called dark age and forgot the heritage of Greek science which now we call Mediterranean science because of the wide expanse of the origin of Greek science. Towns of Europe gradually became derelict. The Eastern Byzantine empire however flourished Constantinople, being the gateway between the West and East for trade and commerce continued for 1000 years until it was overcome by the Ottoman Turks in 1453 A.D.

From Thales of 7th century B.C. till Claudius Ptolemy of the 2nd century A.D. there was a tremendous expression of outpourings in different fields of culture in science, philosophy, politics, sociology, mathematics, drama and medicine. When Athens eclipsed as a seat of learning and research the library of Aristotle was shifted to Alexandria which because of the patronage of Ptolemy dynasty had become a great centre of learning. Here worked scientists like Euclid, Archimedes, Eratosthenes, Aristarcus & Claudius Ptolemy, to name a few. The Alexandrian library had about 4,00,000 manuscripts. A museum was also established which flourished during the rule of Ptolemy Soter.

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In 269 A.D. Septimian Xenobia, the queen 'of Palmyra, attacked Alexandria and burnt a part of the library and museum. In 415 A.D. a Christian mob led and instigated by Cyril, the bishop of Alexandria destroyed the museum & library. The final burning of the museum & library was done by the Islamic attack in 641 A.D..

When attacks started on the Alexandrian library the persecuted Nestorian Christians, an Eastern heretic sect, left Alexandria with Greek texts and took shelter at Edessa, a Greco-Roman city, in the south of Turkey where a theological college was set up. They translated a number of Greek scientific and philosophical works into Syriac which had replaced Greek in Western Asia by the 3rd century A.D.. When Edessa was shut down in 489 A.D. the Nestorians moved to the great Iranian intellectual centre at Jundishapur. This had been set up by the Sassanian monarch Shapur-II. The arrival of the Nestorians raised the reputation to an enviable position. Other Christians from the Eastern churches also made their contribution. In the 6th century A.D., Sergius, a Monophysite priest, technically another heretic sect, translated into Syriac the philosophical works of Aristotle as well as those of the philosopher Porphyry, the 3rd century A.D. Neoplatonist, the works of Galen and various treatises on agriculture.

Arabs in history

A new chapter starts with the arrival of Arabs and Islam in world history. All through the ancient history the kingdoms of Assyria, Babylonia and Egypt found their Arab neighbours a perpetual nuisance. Whenever the military power of settled civilization weakened Arab raiders came down to raid the country and then to settle in the rich and productive territory and reap the benefits of civilization, usually subjugating the un-war like people who were already settled in the valleys.

Mohammed was born in 571 A.D. and died in 632 A.D.. Mohammed united the disparate Arab tribes into a political and religious fraternity. Mohammed himself travelled all over Arabia. Later he became a prophet and preached one god. Mohammed himself was a great seeker of truth. Prophets' concern for knowledge and science will be evinced by some of his sayings. Mohammed said, "To listen the instructions of

science and learning for one hour is more meritorious than attending the funeral of thousand martyrs — more meritorious that attending the prayer for thousand nights"; "With knowledge the half of good rises to the highest of goodness and noble position."

Within prophets' lifetime educational institutions grew up which latter on developed into great universities. Ali, the son-in-law of the prophet and the fourth Khalif lectured on different branches of learning. His recorded sayings are: "Eminence in science is the highest of honours"; "He dies not who gives life to learning"; "Greatest of moment of man is erudition." Such sentiments of the prophet and his disciples animated all classes for a desire for learning.

Within 100 years after Mohammed's death in 632 A.D. Islamic empire spread to Syria, Persia, Egypt, North Africa, Central Asia, Spain etc. A vast area came under the spell of Islam. When Islam conquered new areas in Persia and Roman areas they preferred them to remain toilers as before and themselves to live on the produce of their labour. The Arabs did not force the conquered people to embrace their religion. They left the conquered population to follow their own religion, laws, customs and use their own language. Because of this there was a fusion of the indigenous arts, sciences and the knowledge and the Arabic style of Islam. In this way they absorbed the sciences of the Greeks from many Hellenistic cities as well as cultures of Sassanid Persia, Central Asia and the sciences of India, the ideas of Judaism and Christianity. Until the days of the Crusades in the 11th—12th centuries Syria and Egypt were practically Christian lands under the rule of Muslim Arabs. Their rule was mainly confined to the collection of taxes.

Arabic culture under the Abbasids (from al-Abbas, the first Abbasid Khalif) had closer access to the Persian and Central Asian traditions and closer contact with India which brought to it a renewed vigour and new creative expressions. The second Abbasid Khalif al-Mansur made Baghdad the new capital. He was guided in this choice by his minister, the Persian Khalid-ibn Barmak. Many famous learned men from Kufa and Basra, who formed the academic aristocracy, made Baghdad their home. They looked at the Abbasids as semi- Persians. During al-Mansur's rule an Indian Pandit Kanka presented him the great Indian mathematical treatise "Brahmasphuta Siddhanta" by

Brahmagupta. al-Mansur got it translated as 'al Sind Hind' by his great scientist al-Fazari.

In 765 A.D. al-Mansur became ill. The Nestorian physician of Jundishapur hospital was called to treat him. He was Jirji ibn Bukhtyiushu, the head of academy and hospital at Jundishapur. This was the first contact at the court of Baghdad with the family of Bukhtyiushu which afterwards played an important role in the cultural education of the Arabs. Of all the East Persians who had helped the 'Abbasid revolution' and afterwards came west to share the prosperity of the new dynasty, the most distinguished belonged to the wealthy and well-borm family of Barmakids, originally of Balkh in Bactria, but afterwards settled in Marw (Merv) in Sogdiana.

The Barmakids were keenly interested in Greek science, which was the subject of much attention at Merv. Harun al Rashid, son of ibn Barmak, the head of the family of Barmaks, at one time governor of Armenia and later Khalif of Baghdad in 786 A.D., was educated in Persia and was greatly under the influence of Barmakids.

The golden age of Islam was during the reign of al Mamun (9th century) who came to power in 813 A.D. and ruled till 832 A.D.. He was the governor of Merv. He assembled in his court at Merv a host of scientific and learned men from different regions of Islamic empire. When he shifted to Baghdad he brought with him the scientists, philosophers and engineers like the mathematician al Khwarizmi, philosopher and scientist al-Kindi, mathematician Habas al Habib and engineers like Banu Musa brothers. al-Mamun showed favour to the liberal Mutazilite movement, which believed that faith could be supported by rational arguments. They based their modes of reasoning in the methods used by the philosophers of Greece and Alexandria.

al Mamun set up at Baghdad the 'Bayt al Hikma' or House of Wisdom where a whole body of translators, many of them Christians, were recruited. Where manuscripts of more important texts did not exist, al Mamun got them imported from Byzantium. During al Mamun's reign Ptolemy's work on astronomy was brought from Constantinople and translated as 'Almagest', a corruption of Arabic 'at majisti'. During his rule Indian numerals started being used in Arabia and transported to Europe later in the 13th century as Hindu-Arabic numerals.

Great universities sprang up in different regions of Islamic empire at Toledo, Granada and Cordoba in Spain, Salerno, Cairo, Baghdad etc. The Fatemite library in Cairo contained 1,00,000 volumes all elegantly bound. It had 6500 manuscripts on astronomy and medicine alone. The Library of Spanish Khaliffs had 6,00,000 volumes with 44 catalogues. Every library had departments for copying and translation.

The Islamic world not only translated and preserved the Greek contribution to world culture, which was lost to the West after the fall of the Roman empire and Europe entering into a dark age, but gave birth to a host of scientists and philosophers who made original contribution in different disciplines of learning. From the 9th to 12th centuries great contributions were made in the fields of astronomy, mathematics, optics, chemistry, medicine, geography and other disciplines. al Khwarizmi, who had come to Baghdad along with al Mamun from Merv, developed the method of mathematical computation al jabr and al Muqubula. From al jabr came the word algebra. al Khwarizmi was a great mathematician and astronomer. He wrote an abridged version of al Sind Hind, the Arabic translation of Brahmagupta's work.. al Hayatham (about 1038 A.D.) wrote on optics which was translated into Latin in 12th — 13th" centuries as 'Optical Thaesarus'. The book remained as a standard textbook on optics in Europe till the middle ages. One of the greatest of Arab philosophers was al Kindi (9th century). He had written 150 works on philosophy, astronomy, medicine and other sciences. Having read Plato and Aristotle he also studied Plotinus, the founder of the Neo-Platonist school of philosophy. He is the founder of oriental Aristotelism. ibn Sinna (Avicenna to west) was the greatest product of Arab renaissance. He was a great medical authority and philosopher. Omar Khaiyam (11th century), whom we know as a great poet, was better known in his time as a mathematician and astronomer.

The European languages are still marked by Arabic words which indicate the special importance of Arabic study in European cultural area which will be discussed shortly. Zero, Cipher, almanac, algebra and alchemy are among them. In commerce words like — tariff, douane, magazine are reminders of Arab superiority in commercial techniques. Arab merchants taught Christians how to keep accounts. This cultural traffic upto a certain point of time was entirely one way.

Hence, when Europe went into the so-called 'dark age' Islam preserved, nursed and enriched with sedulous care various branches of science and learning during the Middle Ages. One is struck by the detached rationality of treatment of Islamic scientific works — an attitude similar to modern scientific attitude. The social position of the scientists in early Islamic culture was not essentially different from what it had been in the late classical times. The secular and commercial background to Islamic science marked it of sharply from that of medieval Christendom which was almost exclusively ecclesiastical. Islamic science resembled more that of renaissance Europe. The Arabic science was patronized by Khalifs, wealthy merchants and nobles. It was the strength and also a source of weakness of Islamic science. When the patronage broke down science also decayed. After 11th century Islamic science lost its vigour. They were no longer a part of widely based living movement. Also, after the 11th century Asharites condemned the overzealous use of reason by the Mutazilites, who believed that the faith can be supported by reason. For nearly two centuries the rival schools wrangled with each other until during the 12th century the Asharite arguments carried the day and Mutazilites lost. Intellectual traditionalism won the day. The political and economic breakdown was accelerated by the arrival of new waves of raiders from the Steppelands — the Truks and the Mongols which effectively sterilized the Arabic culture by the 13th century. As the economic progress halted the intellectual stimulus also vanished. The drama of resurgence of intellectual activity in Europe starts when Arabic culture and science was declining after the 11th century.

Europe in the Middle Ages

When the Roman empire collapsed in the 5th century A.D. the network of communication between different areas was maintained by the church. When the Roman legions withdrew, the administration of the areas fell into the hands of bishops and clergy who could read and write which the new rulers could not. For this, the church was granted many privileges, particularly exemption from taxes, while the church itself exacted a tax of one tenth from its own tenants.

By the 8th century Europe was filled with churches and

monasteries of Benedictine order. St. Benedict (480 — 543 A.D.) formulated a rule that "to work is to pray". Benedict wanted that his monks should have 'dirt under their nails'. The churches and monasteries provided services that no civil community could provide in the absence of a centralized power. They ran mills, pack horses for messages and freight services of wagons within a radius of *150* miles from the churches. Churches had a bishop to bishop communication network. It continued right through the "dark ages" connecting one kingdom with the other, carrying news and information as well as ecclesiastical business and transmitting knowledge in the form of copies of manuscripts.

The scientific inheritance of Latin West was limited exclusively to fragments of Graeco-Roman learning such as had been preserved in the compilation of the Latin encyclopaedists. The Romans made hardly any contribution in the sciences. Its contribution was in law and in civil construction. One of the most influential compilation; which survived through the Middle Ages as a text book was the "Natural History" of Pliny (23 — 79 A.D.), which Gibbon described as an immense register in which the author has "deposited the discoveries, the arts and the errors of mankind". It cited nearly 500 authorities. Beginning with the general system of cosmology it passed on to geography, anthropology, physiology, zoology, botany, agriculture, horticulture, medicine, mineralogy and the fine arts. Pliny's was the largest known collection of natural facts until the 12th century.

The mathematics and logic of the Latin West rested on the works of the 6th century Boethas. Boethus did for those subjects what Pliny had done for natural history. Not only did he compile elementary treatises on geometry, arithmetic, astronomy and music, based relatively on the works of Euclid, Nichomachus and Ptolemy, but he also translated the works of Aristotle on logic into Latin. Of these translations only the "Categories" and the "De Interpretatione" were widely known before the 12th century. Knowledge of mathematics was only confined to arithmetic. "Geometry of Boethus" contained only a fragments of Euclid.

Another compiler of the early Middle Ages who helped to keep alive the scientific learning of the Greek in the Latin West was the Visigothic bishop Isidore of Seville (560 — 636 A.D.). His "Etymologies" remained popular for many centuries as a

source of knowledge of all kinds from astronomy to medicine. In the 7th century Severus, a Syrian bishop praised in his writings Indian astronomy and 9 different Indian digits which later became Hindu-Arabic numerals. From the 7th century onwards the Latin West had to rely almost exclusively for scientific knowledge on the above compilations, to which were added those of Venerable Bede (673 — 735 A.D.), Alcuin of York (735 — 804 A.D.) and the German Herbanus Maurus (776 — 856 A.D.).

Charlemagne united a part of Europe in the 9th century and brought in the Carolingian renaissance. Charlemagne invited Alcuin from Northumbria to become his minister of education. One of Alcuin's essential reforms was to establish schools associated with the most important churches and cathedrals. The curriculum was based on the works of Pliny, Boethus, Cassiodorus and Isodore. Between the time of Pliny (1st century A.D.) and the 12th" century, Neoplatonism was assimilated. St. Augustine (354 —430 A.D.) was under the profound influence of Plato and the Neoplatonists such as Plotinus (3rd century A.D.). St. Augustine was the principal channel through whom the Greek thought passed into the reflections of Latin Christianity. According to this school of thought eternal forms or ideas existed quite apart from any material object. The human mind was one of these eternal essences. Because of such idealistic ideas scholars took little interest in the natural world.

In the field of sciences very little was produced during the Middle Ages. But in technology there had been significant developments. From the 5th to 10th century there have been constant references to mills. In most cases owners were the churches which earned profit from such mills. They had the knowledge to construct the mills and the literacy to work out accounting to run a business.

In the 9th century there was a breakthrough in technology with the use of cam. The first reference to it appears in 890 A.D. in the monastery of St. Gaul where it was used to make beer for the monks. The coupling of cam with water wheel gave Europe the power source it needed almost at the right time, as the Viking invasion (Norsemen) from the north and the Arab incursions from the south began to peter off and peace started descending in Europe.

The community who utilized technology with gusto were

the Cistercians, a Christian sect which grew out of the Benedictine Order. By the 11th century the Benedictine monks had grown fat and rich from their estates. The simplicity of their daily rituals had given way to elaborate services, ornate churches and vestments. This decadence led a monk called Robert of Molesme of France to leave the Burgandian Church with 20 of his fellow revolutionaries in 1098 A.D. and set up a rival concern in a poor, marshy part of the Burgandian forests known as Citeaux- after which they were called Cistercians. The third Cistercian abbot, an Englishman Stephen Harding, gave an order that made the Cistercians the most advanced technological community in Europe. The most important decree was that the foundations of new abbeys were to be "far form the haunts of men." It was to scatter the brother monks from the urban life. Harding's edict was: 4 hours of prayer, 4 hours of study and meditation and 6 hours of manual work.

Most of the abbeys were situated where a stream was flowing through the centre of the property. Cistercians rapidly became the master of making marginal lands productive. By the end of the 12th century, 102 years after they had begun, there were 530 houses all over Europe, each of them being a medieval factory. By 1300 A.D. they had foundries with associated mills for treating ore, fulling mills, corn mills, water- powered workshops where tools were made and wool treated, with forges, oil mills, wine presses and all the equipment and administrative organization to run the vast business concerns which many of the abbeys had become.

Cistercians became Europe's best land managers. The leases they gave contained instructions on irrigation, mill use and upkeep, husbandry, land clearance, crop rotation and management of finance. The order opened warehouses and finance offices at major seaports to facilitate exports of commodities for which they had become famous by the 14th century. Cistercian wool was the best available. The textile centres of Flanders would consume every pound of wool that Cistercians made. As peace descended from the 10th century the travels became safer and there was a natural urge of different communities with surplus to move to areas where there was deficit, in exchange of profit.

The first area in Europe to settle after the end of the 10th century is the Champagne region of France which was the

crossing point of ancient trade routes. From 1114 A.D. onwards we hear about Champagne Fairs: at Troyes, Provins, Lagny and Bar-Sur Aube. Champagne fairs attracted merchants from extraordinary distances: from Flanders with cloth, from Luca in Italy with silk, from Spain, North Africa and Provence with leather, from Germany with furs and leather. Luxuries from the East were brought through Venice: spices, wax, sugar, alum, lacquer. From all over Europe came horses, livestock, jewellery, grain, wine, dye-wools and cotton. What followed from 10th to 14th centuries was a Medieval Industrial Revolution.

Cam was used to activate suction pump raising water from mines and wells, to work on a crank to turn the rotatory motion into horizontal motion back and forth for operating knives and saws, to crush malt for making beer. 100 years later it was used in hemp mills in Southern France. By the 11th century there were forge hammers in Bavaria, oil and silk mills in Italy. By the 12th century, there were sugar cane crushers in Sicily, tanning mills pounding leather in France, water-powered grinding stones for sharpening and polishing arms in Normandy and ore crushing mills in Austria. From then on use of water power in every conceivable craft: lathes, wire making, coin producing, metal slitting, saw mills and perhaps most important of all in Liege, Northern France, in 1348 A.D. the first water-powered bellows for providing draught for a Blast Furnace. It was the church that was at the forefront in the use of technology. It was the Cistercians that exerted so profound an influence on the medieval Europe.

Spread of Eastern Science to the West

From the 10th century a lot of information about the great libraries in Spain had reached Europe. The Cordoba library alone had 6,00,000 manuscripts more than the total number in France. European scholars started taking interest in this store house of knowledge. The first to appear was Gerbert (943 — 1003 A.D.), later head of the Cathedral at Reim (in France) and still later the Pope (renamed Sylvester II). This lowborn priest in 960 A.D., at the age 17, was sent to northern Spain, still under Christian control, to study under Otto, the bishop of Vich in Catalonia. He saw how extensive was the corpus of Arab knowledge. Gerbert was the first European to teach and argue for 'the influence of

stars'. He wrote a treatise on astrolabe and other astronomical gadgets. He wrote on arithmetic and geometry depending probably on Boethian tradition which dominated the western church schools and had not improved since the time of Boethius (480 — 524 A.D.). Gerbert was the first to have taught Hindu-Arabic numerals.

By 1000 A.D., Arab medicine was introduced into Europe, at the school of Salerno in south Italy. The basic medical curriculum came from the Arabs, thanks to the renegade Muslim, Constantine the African, turned Christian. After studying in Baghdad, Constantinople and India he returned to his native city, Carthage. He then moved to different places and came to the abbey of Montecassino, where together with another Arab, John the Saracene, he translated the Arab medical text called "The Royal Book" written in the 10th century by Ali Ibn Abbas, physician to the Khaliff of Baghdad. The Latin translation is called "Liber Panlegni".

By the 12th century the medical school at Salerno became very famous, specially in the field of surgery. With the first crusade at the end of the 11th century, Salerno became the transit hospital for the crusaders too ill to undertake the journey. Later the school at Salerno became the first university in Europe. The school formalized all it knew in the form of publication of a massive set of medical precepts called the "Rule of Health". The "Rule" became the basis of medical teaching all over Europe upto the 16th century when it had gone into 140 editions and had been translated into all European languages.

The University of Paris was set up in 1170 A.D.. A few years later the Oxford University was set up. As the new medical knowledge spread into Christian Europe from the South, new astronomical knowledge came in from the West, from Spain. Suddenly, the Europeans had got the tools with which to study the universe and investigate the workings of the human body. In the universities of Paris, Oxford and Montpellier, astronomy, astrology and medicine were the principal disciplines.

Another event that further contributed in the intellectual and scientific resurgence of Europe was the fall off Toledo in Spain to the Christians in 1105 A.D.. The Spanish libraries were opened revealing a storehouse of Greek classical works and Arabic works that staggered the Europeans. In 1130 A.D., the archbishop Raimond opened a school of translation at Toledo.

From the 12th century started the translations of Greek and Arabic scientific and philosophical works. At first it was from Arabic to Latin, but by the 13th century there were many variations — Arabic, Spanish, Hebrew and Greek to Latin, or combinations such as, from Arabic to Hebrew and to Latin. Much of the first translations were done in Toledo and Sicily by such men as Adelard of Bath, Gerard of Cremona and Michael Scott. Adelard of Bath (1075 —1160 A.D.), the future tutor of English king Henry II, was responsible for translation of many scientific works into Latin, including one of an Arabic versions of Euclid's 'Element' in 1142 A.D., which remained for Europeans the chief text book on geometry.

Gerard of Cremona (d 1189 A.D.) of Italy went to Toledo in the middle of the 12th looking for Ptolemy's work and there he found one. Before Gerard died in 1187 A.D. he had translated Ptolemy's 'Almagest' into Latin, as well as 90 other texts. The 'Almagest', which is a corruption of Arabic name 'al Majisti', took Europe by storm. In 1270 A.D. Alfonso the Wise, the king of Castille and Leon, ordered a new edition of star tables, adopted from Ptolemy - The Alphonse Tables. It remained the standard reference work for three centuries.

Michael Scott (1175 — 1232 A.D.), famous as astrologer and wizard and mentioned in Dante's 'Inferno' and by Boccaccio, finally settled at the court of Holy Roman Emperor Frederik II, whose kingdom in Sicily was another important route through which the Arab scholarship reached Christendom. Scott was a linguist too. He translated from Hebrew as well as from Arabic and was responsible for the Latin version of commentaries by ibn Rushd (known in Europe as Averroes) and of a number of scientific works and an astronomical text by al-Bitruji.

Various other scholars from different parts of Europe took part in the translation of Greek and Arabic writings. Some of the other translators were Plato of Tivoli, Gurgundio of Pisa, James of Venice, Eugino of Palermo, Herman of Corinthia and William of Moerbeke. It shows the wide range of the translation movement.

Among the firsts to be affected by the burst of this ancient knowledge were the new universities of Paris and Oxford, which were formed by elevating the schools already existing. Paris University from the cathedral school at Notre Dame and Oxford from a school set up in the 9th century by king Alfred. Paris

University quickly became a great centre of Western Christian theology, and by 1220 the mendicant orders - the Dominicans and Franciscan began teaching there. At Oxford, the Franciscans were found to be a considerable force.

Oxford produced two great scientific men: Robert Grosseteste (about 1168 — 1253 A.D.) and Roger Bacon (1214 — 1294 A.D.?), both well-versed with the host of translations then available from the Arabic sources. At Oxford, Grosseteste was the chief lecturer of theology to the Franciscans who came first to the university in 1224 A.D.. Besides theology, Grossesteste set the Franciscans to study mathematics and natural sciences. His influence was immense at a time when the new knowledge of the Greeks and Arabs was having a profound impact on the whole of Christian philosophy. Grossesteste himself wrote important texts on astronomy, on the cosmos, sound and particularly on optics. His thorough knowledge of Aristotle's works stimulated him to write on the nature of scientific enquiry. Science, he said, begins with man's experience of the phenomena, finding the 'causal agent', to analyse for, and break them into component parts or principles, then forming a hypothesis which has to be tested and verified or disproved by further observation. This was the basis of experimental method which was later propounded by Francis Bacon and Rene Descartes in the 17th century. Grosseteste also made an analysis of causal agent using Aristotelian procedure as a starting point towards the classification of the science to show how some are dependant on others. He held that mathematics can only be formal causal agent for a phenomenon, because material, and Aristotelian term "efficient" causes, could only be provided by the material world itself'. Grosseteste made his contribution in different branches of sciences like sound, optic, etc. etc. Stimulated by al Hayatham's 'Optical Thesaurus', referred to earlier, he discussed in detail the behaviour of light rays. His book "On the rainbow or refraction and reflection" clearly shows that he was familiar with the microscopic and telescopic actions of lenses. He wrote, "The part of optics, when well understood, shows us how we may make small things placed at a distance appear as large as we want, so that it is possible for us to read the smallest letters at an incredible distance, or to count sand, or grain or seeds or may sort of minute objects." This is a description of telescope and magnifying glass.

Grossesteste must have worked with lenses and its combination. But the world had to wait for more than 300 years for a telescope to arrive. Grosseteste discovered the laws of refraction of light through a lens, but its complete understanding came only in the 17th century.

Roger Bacon (1214 — 1294 A.D.?) spent his later life in the study of mathematics, languages and especially of optics as well as in the experimental sciences. From the scientific point of view he was the most important pupil of Grosseteste. He showed interest in alchemy and astrology which got him into trouble with the Franciscan order. He was imprisoned for some years for his Averroist (ibn Rushd) views.

Bacon claimed that scriptural authority must be informed by reason and the reason has to be confirmed by experience. He divided experience into mystical experience and understanding obtained through exterior causes, aided by instruments and given precision by the use of mathematics. Bacon wrote his 'Opus Major' (Major Work) in 1267. In this book he drew on the remarks of Euclid, Ptolemy and al Hayatham. The concept of "Laws of Nature" was first introduced by Bacon in his writings.

Albert Magnus (1192 — 1276 A.D.) was a contemporary of Grosseteste and Bacon. His approach was similar to them. Magnus played an important role in introducing Greek and Arabic sciences into western European universities where there was very little science before him. Church authorities in general were opposed then to Aristotle's ideas on natural sciences. The ecclesiastical authorities in Paris condemned Aristotle's scientific works in 1210. Anyone propagating his ideas was heretical to the authorities and was in danger of excommunication until it was revoked in 1234.

Magnus came in contact with Aristotle's works in 1240 A.D. while he was at the Paris University. He paraphrased Aristotle's logic, mathematics, ethics, politics and metaphysics. His scholarship was phenomenal for which he was called "Universal Doctor". He didn't think that Aristotle was infallible. He emphasized the importance of observational evidences. Magnus thought science involves enquiry into the nature of things. His greatest work lay in his own observation of nature. He wrote a treatise "On Animals' and rejected many unfounded popular myths about animals.

With Grosseste, Bacon and Magnus a new culture, previously

lacking, of a systematic study of the natural world dawned in Europe, which was stimulated by the burst of Greek and Arabic knowledge and science. The nature of this knowledge was inimical to revealed religion and was pagan in outlook.

The theological and philosophical thought of Western Europe between the 9th and 15th centuries was called in general Scholasticism. Till the 13th century scholasticism tried mainly to systematize the dogmas of the church fathers and make them intelligible to the untrained minds. From the 13th centuries scholasticism endeavoured to bring in a synthesis between the dogmas of the fathers of the church and the Aristotelian philosophy. This brought in a separation of philosophy from theology through the assertion of some writers about the supremacy of reason over faith. The controversy over reason and faith was there from the beginning of the movement.

According to Johannes Scotus Erigena, the father of scholasticism, reason and faith, philosophy and theology, are in perfect mutual harmony. For him authority is reason and reason is authority. Anselm (1035-1109 A.D.) was the earliest of the scholastics. He was the founder of scholastic realism, the theory that universals (e.g. man in general, iron in general) are real archetype of the particular things (e.g. individual piece of iron or individual man) and that particulars are mere copies of the universals. This is an idea that was derived from Plato. Anselm's views were opposed to the 11th century nominalist Roscellinus, who maintained that individuals or particular things are alone real, and that universals are merely names of abstractions made by mind. The conflict between scholastic realism and nominalism continued through a greater part of the scholastic period.

The chief nominalist among the later scholastics was William of Ockham (about 1286 A.D.), famous on account of his logical rule known as "Ockham's razor", the principle that "entities are not to be multiplied beyond necessity". Peter Abelard (1079 — 1142 A.D.), the romantic figure of scholasticism, took a middle path.

By the beginning of the 13th century, large portion of Aristotle's works became accessible in translations from Arabic with the commentaries of Avicenna and Averroes. Soon ,after this scholasticism bore its finest fruits in the systems of the Dominican Albertus Magnus and St. Thomas Aquinus (1227 — 1274 A.D.) whose great work was, with the aid of Aristotle, to

demonstrate philosophically all the doctrines of the church. He brought in the synthesis between Aristotelism and traditional metaphysics.

Opposed to Aquinus was Roger Bacon who claimed to be a proper Aristotelian than they. His works were more philosophical and scientific than theological. In many respects he is the modem of the scholastics. Bacon's writings alarmed the church. The nominalist William of Ockham emphasized the division of philosophy and theology. Finally the eclectic system of Nicholas of Cusa foreshadowed the beginning of modem philosophy. Other important figures of the late middle ages were: Thomas Bradwardine (?1290 — 1349 A.D.); John Buridan (about 1295 A.D.), famous for his allegory 'Buridan's ass' implying the problem of choice between equally desirable alternatives; Nicole Oresme (1320 — 1332 A.D.), a strong opponent of astrology and opposed to Buridan's idea of divine gift of impetus to planets.

With the revival of Greek learning in the West the footstep of renaissance was heard in the 13th and 14th centuries, and the three great flowers of the early renaissance were Allegherai Dante (1265-1341 A.D.), Boccaccio and Petrarch (1304 — 1347 A.D.), the founder of humanism. The Eastern Roman empire which continued for more than a thousand years after the fall of the Western Roman empire had fallen to the Ottoman Turks in 1453 A.D.. Many Greek scholars of Constantinople took shelter in different cities in Europe, especially in Italy.

Printing Revolution

In 751 A.D. China sent a team of paper makers to Samarkhand to set up a paper factory when Samarkhand was overrun by the Arabs. The Arabs took away the technicians for paper making for which there was a growing demand due to copying and translations in various universities of the Islamic empire. Between 1347 — 1407 A.D. the black plague ravaged Europe and the population of Europe was halved. This was the time when Europeans were translating the Greek and Arabic works. There was a great dearth of technicians and scribes because of the plague. The need for printing was being felt in the society.

Johannes Gutenberg, son of a metal smith of Germany, invented movable types for printing. In 1457 A.D. there was

only one press at Mainz, but by 1480 A.D., within 23 years, 110 towns had printing presses. Printing made books available to many. The knowledge, which was available only to scholars, now became available to many. Knowledge became democratized. By 1515 A.D. when Aldous Manuitus died, all major Greek works were published.

By the 15th and 16th centuries there were three very important developments, thanks to various factors namely, vis-a-vis renaissance, exploration and discoveries and scientific revolution.

High Renaissance

The revival of learning and discovery of the thoughts of ancient Greece, the Arabs and the East laid the foundation of high renaissance in Europe in the 15th and 16th centuries. The spirit of renaissance was self-expansion, humanism, breaking the fetters of authority and traditions. We find in Europe an efflorescence of culture in different fields. To name a few great renaissance personalities — Leonardo da Vinci, Michael Angelo and Raphael in Italy, Albrecht Duerer in Germany, Erasmus in Holland, Cervantes in Spain, and to climax it all, Shakespeare in England. Emphasis was laid more on human affairs than spiritual. Man becomes the measure of all things. The rèvival of what is human finds expression in those wonderful lines of Shakespeare:

"What a piece of work is Man!
How noble in reason
How infinite in faculties
In form and moving how express and admirable
In action how like an angel
In apprehension how like a god
The beauty of the world
The paragon of animal."

The renaissance spirit engulfed all parts of Europe like a surging volcano.

Exploration and discoveries

By the end of the 13th century the magnetic compass had been in general use in sea voyage. By 1270 Alfonse the Wise

ordered that all sailors should carry compass. In the 13th century Marco Polo had already travelled to China from Venice and from his writings Europe learnt about rich cities of China, the golden towers of Japan, the pagodas of Burma and Thailand, the spices of East Indies and the luxuries of India. When Constantinople fell tc the Ottoman Turks in 1453 A.D. the land routes between Europe and Asia was cut off. So Europe needed a alternative trade route. Hence, the countries in Europe which were on Atlantic coast started marine expedition from the end of the 15th century. The exploration went on for about 200 years. We had explorers like Barthelomew Diaz (1481 — 1500 A.D.) who reached the Cape of Good Hope, Columbus (1492) reached America, Amerigo Vespucci (1454 — 1512 A.D.) made two voyages to South Africa, Magellan crossed the Pacific, Vasco de Gama reached Calicut in 1498 A.D. and so on.

Wherever the explorers went the flag of their country and the missionaries followed. They returned back with gold. Columbus said, "God is the most precious of all objects in the world, as also the means of rescuing their souls from the purgatory and restoring them to the enjoyment of paradise".

The effects of exploration and discoveries were the following:

i) Rise of trade giving birth to mercantile capitalism in Europe,
ii) Formation of colonies and plunder,
iii) Slave trade from Africa,
iv) Rise and growth of nation states in Europe,
v) Centre of gravity shifted from the Mediterranean to Atlantic.

By 1600 A.D. the amount of gold in Europe had doubled and that of silver increased ten times. With the growth of trade and commerce the foreign trade in Europe doubled in the decade between 1731 and 1740 A.D. when compared to the decade between 1701 and 1710 A.D.. It doubled again between 1761 and 1770 A.D.. Every European country tried to increase its gold holdings. In economic theory this policy is known as mercantilism.

Many nations were conquered. Many communities were decimated and massacred. Between 1492 and 1538 the number of original inhabitants of Spanish territories of Haiti and Dominican Republic reduced from 2,50,000 to only 500. Charles Darwin observed, "Wherever the Europeans have trod death

seems to pursue the aboriginal." By the 18th century colonialism was established in a large part of the world which is today the so-called third world between the tropics. The loot from the third world started reaching the west. This formed a part of the primitive accumulation of capital which was necessary for the ushering of the Industrial Revolution.

Protestant Reformation

We have always seen in history that rebel sects have always appeared in different religions. In Christianity early attacks on the authority of Pope came from England and France. John Wycliffe of England in the 14th century translated Bible into English. It was a heretical act, because at that time Bible was available only in Latin which was the official language of the Church. John Huss (1369 —1415 A.D.), a pupil of Wycliffe, a professor of Prague was burnt to death for his heretical views. Erasmus, a renaissance scholar of Holland, severely criticized the excesses of church and the clergy through his writings. He pleaded for a return to simple teachings of Jesus. Erasmus tried to reform the church by an appeal to reason.

The revolt came in the 16th century from Martin Luther (1483 — 1546 A.D.) of Germany. In 1511 Luther visited Rome and his eyes opened to the degrading evils which underlay the specious piety of the church. In 1517 Luther revolted against selling Letter of Indulgence issued by Pope Leo X. On October 31, 1517 he pasted his protest-bill on the door of the church at Wittenberg. This day may be reckoned as the birthday of Reformation. The rich and the poor, nobles and marchants rallied behind him. Within 17th century half of Europe became Protestant. Protestant Reformation helped in the secularization of the European Society.

Scientific Revolution

Renaissance and printing revolution opened up the spirit of men in Europe. In various branches of science a new interest was generated with the new knowledge of Greek and Arabic sciences bursting into Europe. In botany, zoology, mechanics, mathematics, astronomy, chemistry etc. fundamental observations and new outpouring started. Important scientific

observations were made by the renaissance personalities like Leonardo da Vinci, Albrecht Duerer and others.

In Botany we find the German fathers of Botany who became Lutherans — Otto Brunfels (b. 1489 A.D.), Jerome Boek (16th century) and Leonard Fuchs. In zoology the most notable encyclopaedic naturalists were Pierre Belon, Guillome Rondelet and Konrad Gessner.

In chemistry, Parselsus was called the father of modern chemistry (1493 A.D.?). His main contribution was in his theory of disease. He was the first to contribute a complete system of chemistry. The book on mining and metallurgy that is famous was written by Georg Bauer (1555 A.D.) of Agricola. William Gilbert (1540 — 1630 A.D.) of England wrote his famous "De Magnete".

The two books that revolutionized man's conception of the Universe and about himself were "De revolutionisbus celestium orbium" by Copernicus and "The fabric of human body" by Andreas Vesalius. According to Thomas Kuhn, "Copernican revolution was a revolution in ideas, a transformation in man's conception of the universe and of his own relation to it, culminating one and half century later in the Newtonian conception of the universe." The time was ripe for the birth of Galileo Galelei (1564 — 1642 A.D.) who brought the modem world into being by turning his telescope towards the sky. We enter seventeenth century and there was no turning back.

The Scientific Revolution was a period of great concern over Method. Insight and intellect were not considered more important than sound principles and procedures. Every treatise of the 17th century begins with a discussion on Method or a methodological statement. Descarte's "Discourse on Method" (1637 A.D.) and Newton's "General Scholium", the conclusion of Principia (1713 A.D.) were examples. The most important and novel aspect of the new science was the combination of mathematics and experiment. Whereas the previous understanding was based on the authority of saints, revelations and Holy Writ, the science of seventeenth century was held to be dependent on empirical foundation or good common sense. Anyone who could conduct experiment could verify the truths of science. This methodological approach differentiated the modem science from the traditional knowledge. Anyone who could master the method could make discoveries or find new

knowledge. It was t‑‑is one of the greatest democratizing forces in the history of human civilization when discovery of truth no longer was legislated by a chosen few in the society.

Francis Bacon (1561 — 1626 A.D.) and Rene Descartes (1596 — 1650 A.D.) were the outstanding codifiers of scientific method. Bacon did not recognize the importance of mathematics in scientific theory. Bacon downplayed the conceptual innovation which had a very important role in the advancement of science. Bacon separated science from religion and metaphysics. Bacon wrote in "Novum Organum", "The true and lawful goal of sciences is none other than this: that human life be endeavoured with new discoveries and power".

Descartes gave the method of studying a phenomenon. He said, break things apart into simple components and study them to understand the phenomenon. This is perhaps the extension of the controversy in the 11th century over universal and particular. But this process of looking at nature gave birth to a reductionist epistemology in the post-Industrial Revolution society. Friedrich Engels, in the 18th century wrote in 'Anti Duhring', "The analysis of Nature into its constituent parts were the fundamental conditions for the gigantic strides made in our knowledge of Nature during the last 400 hundred years. But the method of investigation has left us a legacy of the habit of observing natural objects and natural processes in their isolation detached from the vast interconnection of things." This tunnel vision of the reductionist epistemology of modem science is creating a wide spread ecological instability endangering the very survival of human civilization.

Scientific Societies

Post—renaissance society and the ushering in of the scientific revolution brought in a new age when human spirit was striving to break the fetters of authority and tradition. New institutions were needed in Europe which would foster this new spirit. Francis Bacon dreamt of such an institution in his 'New Atlantis' (1627 A.D.). Scientific societies started appearing in Europe to satisfy the need of this new age. Academi dei Lincei was established in Rome in 1601 of which Galileo was a member. In 1657 started the Academy of Experiment in Florence. Its moving spirits were Toricelli and Viviani, two pupils of Galileo.

The famous Royal Society of England was established in 1660 by the informal adherents of Francis Bacon's experimental philosophy. The Royal Society was the realization of House of Solomon of "New Atlantis". Newton was the president of Royal Society from 1670 to 1729 A.D. till his death. Academy of Sciences, Paris was established in 1666 A.D. by Descartes and Pascal. Berlin Academy was established in 1700 A.D. at the initiative of Leibnitz who was its first president.

Parliamentary Revolution in England

With the advent of renaissance and reformation, traditional views were being challenged in the 17th century and ideas of religious liberty, political equality and individual freedom started growing. Scientific Revolution brought in an understanding of the physical world and brought in the questioning of established beliefs.

Between 1642 and 1649 England had civil war and Charles-I was beheaded in 1640. Under Cromwell parliament became victorious. After many vicissitudes, in 1688 came the glorious Parliamentary Revolution with the final supremacy of parliament over monarchy and the inauguration of constitutional monarchy. This was the time feudalism was breaking down in Europe and mercantile capitalism was growing and profound changes were coming in land management.

Changes in Agriculture

Between 1600 and 1750 A.D. far reaching changes took place in the agricultural management, which increased the productivity substantially. At the end of the 16th century 1000 years old 'open field system' was used in Europe with two-field system producing two crop rotation (One crop and one fallow). The following changes came in:

i) four-field system — yearly crop rotation of clover, wheat, turnip and barley,
ii) Enclosure system,
iii) Introduction of new crops,
iv) Improvement of livestock,
v) Introduction of seed drill and horse hoeing.

Age of Englightenment and Reason

It has already been discussed that far reaching changes in the 15th and 17th centuries opened up the minds of the Europeans. They started questioning the age-old beliefs and traditions. Gradually this questioning engulfed all aspects of human thought leading to the Age of Enlightenment and Reason in the 18th century. It looked at the world with a new rationalism that nearly severed any connection between the natural world and God's continuing concern with it.

It started in the 17th century when Europe became aware of the religion and culture of non-Christian nations due partly to the reports of the Jesuit Missionaries who found exemplary and virtuous men some of whom had no religion at all. Though they did not have divinely revealed religion yet they have some kind of natural religion. After Newton's synthesis of 'Principia' this view looked at god as an Architect and a mechanic than a heavenly father. God had created the world but once created it obeys the laws of nature. From then onwards biblical prophecy became unacceptable, miracles unthinkable, and the Holy Writ itself was called into question.

In England, in 1620s, Edward Herbert, a diplomat historian, metaphysical poet and philosopher published in Paris his book "On Truth". Herbert claimed that "Instructed Reason" was the surest guide to truth. A belief called Deism, a natural religion, was launched with the publication of Herbert's book. The end of Deism came with the publication of Thomas Paine's (1737 — 1809 A.D.) book "Age of Reson". Deism was never an organized movement. This outlook flourished in France because of the disillusionment and discontent with Louis the XIV's rule.

One of the greatest advocates of Deism was Voltaire who got acquainted with this view when he visited England in 1726 A.D.. Voltaire was already committed to anti-Christian rationalism. In 1728 he wrote his "Philosophical Letters" which expounded his Deist views. Later, in 1760, he wrote "Philosophical Dictionary" which one commentator called a compendium of malice against Christianity. Jean Jacques Rousseau was also a supporter of Deism as expressed in his book 'Emile' (1762) and "The Social Contract" (1762).

John Locke (1632 — 1702 A.D.), in 1690 A.D. published his book "An essay concerning human understanding", where he

applied the methods of Galileo and Newton to the study of man. Locke saw in experience the measure of human knowledge of realities amidst which man finds himself Locke says, "Let us suppose mind to be white paper without any ideas. Whence has it all the materials of reason and knowledge? To this I answer with one word — from experience. Our observation, employed either about external sensible objects, or about the internal operations of our minds, is that which supplies our understandings with all the materials of thinking. These two are the fountains of knowledge". Locke said that environment makes man what he is; improve environment and you improve man.

In 1697 A.D. Pierre Bayle published his "Historical and critical dictionary" aimed at demolishing the 'vices of religion'. In France, physician Julian la Mettrie in his "The Man — Machine" (1747) took a totally materialistic view. Man was reduced to nothing more than matter in motion and he even went further to say, "We are no more committing a crime when we obey our primitive instincts than the Nile is committing with its floods or sea with its ravages".

A totally materialistic attitude was also expressed when philosopher Denis Diderot and Jean d' Alembert, the mathematician and the secretary of French Academy of Sciences, edited the famous 33-volume "Encyclopaedia or classified dictionary of sciences, arts and trades" between 1751 and 1777. The dictionary was the compendium of the new rationalistic view that was dawning in Europe containing severe criticism of religion and establishment. Its influence in European minds was immense.

The late 17th and the 18th centuries were therefore times of great philosophical changes, attentions in man's outlook about himself and an attack against authority, tradition and established beliefs of western Christian religion.

Serfdom and Guild System

By the beginning of the 18th century serfdom and guild system, the two obstacles to the advent of Industrial Revolution and Factory System, restricting the mobility of worker, had been almost completely broken in England and in France during the French Revolution at the end of the 18th century (1789 A.D.).

By the 16th century cities differentiated from the villages. Trade had become internationalized. The Guilds could not satisfy the market. By the 16th century, mercantile capitalism had already been established. In England in the 16th century products like cloth, socks and metallic products were made in villages. This system known as Domestic System, spread in Germany and France later. Gradually, division of labour appeared. One workman does not produce the whole product but a part of it. In the Guild and Domestic Systems the craftsmen were the owners and sold the products to the traders. Factory system appeared in which labourers sell their labour power. After 1750 the Domestic System started giving way to the Factory System.

Industrial Revolution (1760 — 1830)

The social, political, economic and scientific technological changes that took place till middle of the 18th century ushered the Industrial Revolution which brought in profound changes in society.

The first impact of the Industrial Revolution was felt in the textile industry. Prior to 1760 machinery used for spinning cotton in England was as simple as in India. The English iron industry was in decline because of deforestation.

Many of the technological discoveries remained unutilized before the Industrial Revolution. John Kay discovered Flying Shuttle in 1733. Wytt patented Roller Spinning machine in 1738. An authority on English industrial history, W. Cunningham commented, "The introduction of extensive implements and processes involve a large outlay; it is not worthwhile for any man, however energetic, to make the attempt, unless he has a considerable command over capital and has access to large markets. In the 18th century these conditions were more and more realized." The increase of trade, commerce, colonization, slave trade and plunder of colonies made accumulation of capital and establishment of markets possible.

Lord Clive wrote that Murshidabad was a much more populous and flourishing town than London when he entered Murshidabad during Battle of Plassey. Letters of Lord Clive to the Directors of East India Company show that the net revenue sent to the Directors of East India Company was £ 1,650,900

after paying all costs of administration and pension to the Nawabs and tributes to the Mughal ruler. After the Bengal plunder started arriving in England the effect was instantaneous. Brook Adams in his "Laws of Civilization and Decay" writes, "Edmund Burke said when he came to England in 1750, there were only 12 bankers' shop in the provinces, though in 1790 they were in every market town".

Inventions which were dormant or were discovered started being introduced immediately. Flying shuttle was used in 1760. It quickened weaving. Hargreaves invented Spinning Jenny and got it introduced in 1768. Production of thread increased. Watt matured in 1768 the steam engine which powered the Industrial Revolution. Richard Arkright invented in 1769 Water Frame and got introduced. In 1770 Samuel Crompton contrived the Spinning Mule joining Spinning Jenny and Water Frame. In 1785 Dr. Edmund Cartwright patented power loom. Coke, which was invented by Derby in 1709, was used in Blast Furnace by the end of 18th century. By the 18th century Dr. Samuel Johnson was moved to state that, "The Age was running after innovation." Mercantile capitalism gave place to free trade capitalism.

Industrial Revolution gave man an immense power over nature. The society started giving shape to Francis Bacon's dream of acquiring the 'fruits of science' at an escalating scale. The world was differentiated into developed and underdeveloped worlds. The difference between rich and poor of the world went on increasing. An extra 5 billion people were added by 2000 A.D. when in 1830 the population was only 1 billion. The consumption of the industrial world and the rich of the world went on sky rocketing. Due to the gluttonous consumerism, at the end of the 20th century all the five important primary aspects of nature — forest, land, water, biodiversity and air are under severe stress. The reductionist world view of science has created an ecological catastrophy. Only the history of science, technology and society can make us understand the present day world. If we can know the past, understand the present we can mould our future. A new paradigm of development has to be conceived.

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The Science and Technology Policy 2003 at a Glance

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[A draft paper was prepared as the discussion material for a lecture on the title theme in the short-term course on the history of science and technology in the Indian perspective organized by the Asiatic Society, Kolkata, during 17 February-7 March, 2003. It was later improved further on the basis of the experience of interaction with the participants of the course. Now the following is being submitted as the final paper for publication. Dated: 20 May 2003]

In my detailed review of the first Science Policy Resolution adopted at the initiative of Jawaharlal Nehru by the Indian Parliament in *1958,* 1 had shown, among others, that it did not properly identify the main obstacles before the cultivation and development of science in our country. I had pointed out, for example, two grave problems: the prevalence of feudal culture psychology and values among the greater cross-sections of the people — literate as well as illiterate, and, as a consequence, the environment of commandism in the entire science and technology setup — from top to bottom, from the government to the institutions. It, therefore, failed to take into account the two primary tasks required of the science policy in the obtaining Indian socio-political perspective, namely, (1) secularizing the entire society liberating it from the impacts of religious, caste and other particularistic traditions; and (2) democratizing the total structural functional and psychological conditions of the Indian science and technology regime —including education, research, administration and fund.[1] It could, therefore, be legitimately expected that a new policy formulated on the strength of experiences of long 45 years with the last policy would now duly take into account its limitations and failures. Let us proceed to examine.

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I

We have come to know about the emergence of a new policy from the website of the DST (Department of Science and Technology): Science and Technology Policy 2003 dated 10 January 2003.[2] Nothing is stated there about its status — whether it is only a draft paper for discussion or it is already the final policy statement of the Union Government, and in that case, how and where it has been discussed approved and adopted. Several attempts to communicate with the DST to ascertain its status failed to yield any response. We have therefore no way left but to discuss the policy statement as a final product of the Government.

A critical perusal of its text immediately makes the following aspect clear to any body. It does not take into account the basic weaknesses of the previous policy. On the contrary, it turns the first weakness into a virtue. It eulogizes the ancient Indian tradition in the highest possible glorifying terms: "Science and technology have been an integral part of Indian civilization and culture over the past several millennia. Few are aware that India was the fountainhead of important foundational scientific developments and approaches. These cover many great scientific discoveries and technological achievements in mathematics, astronomy, architecture, chemistry, metallurgy, medicine, natural philosophy and other areas. ......India also assimilated scientific ideas and techniques from elsewhere, with open-mindedness and a rational attitude characteristic of a scientific ethos. India's traditions have been founded on the principles of universal harmony, respect for all creation and integrated holistic approach." It also seeks to "utilize the extensive knowledge acquired over the long civilizational experience of India." Thus, far from striving to undermine, we are afraid, it openly seeks to cater to the revivalist elements of our society.

II

While undertaking a detailed analysis of this statement claim by claim, it would be better to hear the opinion of a great Indian scholar of the Sanskrit literature in the 19th

century —Ishwar Chandra Vidyasagar, a towering personality of the Indian Renaissance — as much as are relevant on these points. The policy statement refers to many subjects, but we shall prefer to cite Vidyasagar's observations, first, on the most important of them, namely, mathematics, "In mathematics, Lilavati and Vijaganita are the text books. Lilavati treats of arithmetic and mensuration and Vijaganita of algebra. These two works arc very meagre and from a curious perversion of Ingenuity and obsessed of a right sense of real value and object of such studies, the author has made them so difficult by puffing the rules and questions all in verse that the students cannot go thorugh them in less than three or four years. The examples are very few. **The fact is, the study of Sanskrit-mathematics is not only nearly useless in itself, but it interferes largely with other studies and engrosses a great deal of time and labour which might be employed in far more useful pursuits. Hence the study of mathematics in Sanskrit should be discontinued.** ....I wish to substitute the pursuit of it in English, whence in less than half the time now given to it an intelligent student will acquire more than double the amount of sound information that he could obtain by the most perfect acquaintance of all that exists in the Sanskrit language in the subject." [3; emphasis ours]

On the question of natural philosophy, he observed: "True it is that the most part of the Hindu systems of Philosophy do not tally with the advanced ideas of modem times, One of the principal reasons why I have ventured to suggest the study of all the prevalent systems of philosophy in India is that the student will clearly see that the propounders of different systems have attacked each other and have pointed out each other's errors and fallacies."[4] Thus he was interested in the teaching of the Hindu systems of philosophy not with an expectation to absorb any fruitful knowledge or approach from them but to expose their "errors and fallacies" and thereby to underscore their irrelevance today in full.

Vidyasagar was strongly of the opinion that the resurgence of the country could come only through the adoption of a new philosophy and a new mode of life. He did not cherish any

illusion about the superiority of the Vedic or Vedantic thoughts to the modem western ideas about life and society. In his words: "For certain reasons, we are obliged to continue the teaching of the Vedanta and Sankhya in the Sanscrit College. **That the Vedanta** *(sic!)* **the Vedanta and Sankhya are false systems of Philosophy is no more a matter of dispute.** These systems false as they are, command unbounded reverence from the Hindus. Whilst teaching these in the Sanscrit course, we should oppose them by sound Philosophy in the English course to counteract their influence." [5; exclamation interpolated in the original by Vidyasagar; emphasis ours]

Far from locating any useful information and any valuable foundational approach in the ancient texts, Vidyasagar also pointed out: "It must be confessed however that there are many passages in Hindu Philosophy which cannot be rendered into English with ease and sufficient intelligibility only because **there is nothing substantial in them.**" [6; emphasis added]

As regards the "open-mindedness" and "rational attitude" in the Indian tradition to "assimilate scientific ideas" from elsewhere, as stated in the policy, Vidyasagar had just the opposite and painful perceptions: "It is not possible in all cases I fear that we shall be able to show real agreement between European Science and Hindu Shastra. Even if we take it for granted that we shall be able to point out agreement between the two, **it appears to me to be a hopeless task to conciliate the learned of India to the acceptance of the advancing science of Europe. They are a body of men whose longstanding prejudices are unshakeable.** Any idea when brought to their notice either in the form of a new truth or in the form of the expansion of truths the germs of which their Shastras contain they will not accept. ....They believe that their Shastras have all emanated from Omniscient Rishis and therefore, they cannot but be infallible. When in the way of discussion or in the course of conversation any new truth advanced by European Science is presented before them, they laugh and ridicule. — Lately a feeling is manifesting among the learned of this part of India, specially in Calcutta and its neighbourhood, that when they hear of a scientific truth, the

germs of which may be traced out in their Shastras, instead of showing any regard for that truth, they triumph and their superstitious regard for their own Shastras is redoubled. From these considerations, **I regret to say that I cannot persuade myself to believe that there is any hope of reconciling the learned of India to the reception of new scientific truths."** [7; emphasis added]

III

It is visibly clear from these observations that according to Vidyasagar neither the ancient Sanskrit scriptures of the Vedic and post-Vedic times contained much of useful and veritable knowledge worthy of today's consideration, nor did these foster a critical and comprehending mind — conducive to the growth of science — among the scholars who cultivated them. If it were true in Vidyasagar's time it is naturally much more true in our time when the new policy is being floated. Thus the new policy starts with an already tested and rejected — therefore wrong — perception of the past tradition of India.

First of all, let us point out here an essential aspect of how the policy was born. The policy makers, the present personalities in power involved in the process, are known for their ultra-nostalgic love for and euphoria over the ancient Hindu scholarship, whatever one might construe by this. They had already, long before the policy was proposed, started glorifying, projecting and introducing in the formal curricula subjects like Vedic Mathematics, Vedic Astrology, Vastushastra, Paurohitya, Yoga, and *so* on. It has also been reported in the media that they are thinking over the proposal of introducing another similar course on Guptavidya (occultology), which will probably deal with witchcraft, demonology, magic cure for snake-bite, dog-bite, etc. and shamanism with village deities.*

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* Let us note in passing that these subjects, with these proper names, did not exist in the Sanskrit curricula anywhere of the country during Vidyasagar's time. The subjects and the titles are recent inventions of Dr. Josh and his men. — A. M.

So they really did not wait for a policy to be proposed, discussed and debated among the concerned segments of the population — as is expected in such a case in a democratic system of governance. As far as our information goes, till the date of submission of this paper, the policy was not tabled in any of the two Houses of the Indian Parliament. In fact, it was not even widely circulated among the public nor were their opinions sought. The attitude of the policy designers is: Say what you may like, but we shall go ahead with our own already decided projects. Then what was the use of the facade of a national policy on science and technology? An executive decision of the Union Government actuated by the narrow political-ideological concerns of the main party of the ruling morcha is passed on as a national policy, keeping the people of the country, the scientific community, the opposition in the parliament and even the partners of the government — thus the entire nation as such — in complete darkness about its existence and contents.

This is the kind of appreciative spirit they have sincerely imbibed from the long tradition of the country they quite often exhort upon. This is how the Government has decided to respond to the criticisms of the learned public on the relevant questions.

But, secondly, there are people who are carried away by another aspect of these exhortations. They think: It is wrong to override the democratic process, but it is a good thing to rescue, preserve, cultivate and highlight whatever valuable knowledge was produced in this country of a long past history. If the present Union Government is sincere on that point, its procedural mistakes could even be tolerated. Secularists and rationalists are raising the democratic arguments in order to thwart forever the restoration of the ancient Indian wisdom. Let us discuss that point.

IV

Two things deserve to be placed before them for consideration.

1. We have to decide first whether the ancient knowledge was at all a valid and true system of information in the past context where they belonged.

2. Even if they were true in that relevant context, we have to check whether they are still valid in the present context in which we are living and thinking to assimilate and apply science.

For the first task it should be pointed out here that the Present Government has been doing nothing new in this direction. There have been conducted since the early 19th century many fruitful detailed and thoroughly investigative studies of what were gained as positive knowledge in ancient India, by both Indian and foreign scholars. We may refer here only to a few of such works by some of the eminent authors, for example, Colebrooke[8], Brennand[9], Roy[10], Mukhopadhyay[11 & 12], Seal[13], Kaye[14], Barnett[15], Sarkar[16], Datta[17], Dana and Singha[18], Clark[19], Zimmer[20], Majumdar[21], Sen[22], Basham[23], Kosambi[24], Sircar[25], Bose et al[26], Keswani[27], Chattopadhyay[28], etc. The literature is extended into other languages too, like French and German, for example, see Thibaut[29], Jolly[30], Renou[31], Filliozat[32], etc. Besides these, there are many scores of authoritative papers published in the last two centuries in specialized journals on different aspects of the history of science and technology in India, written by informed specialists.

It should, however, be kept in mind that these authors differ among one another on many aspects of the subject — namely, value, authenticity, reliability and chronology of the facts and their sources, their importance and interpretation, and so on. While some of the Indian authors have the tendency to overestimate the significance of a fact, extrapolate modern discoveries into the past on the basis of meagre data, and even claim credit for many deeds on the strength of speculations, some of the western scholars are inclined to see nothing positive in the past history of India. One may, therefore, rightly consider the research to be far from completed and argue for continuing the study further in any new area — in depth and/or breadth. One may even want to bring the debates and differences among those scholars on many details to a conclusive consensus through some fresh and more elaborate efforts. But that requires launching a grand and long-term comprehensive research project involving a large number of efficient persons capable for the job, free from any kind of

national, cultural or religious prejudices and presentiments, i.e., people who can hold fast to facts irrespective of their personal faiths, creeds and commitments.

The interest behind such a study is *historical* and its purpose is mainly *historiographical.* It is done with a view to situating the knowledge in the context in which it was relevant, where it played a positive role in the on-going cognitive process of man. It is not considered a *subject of knowledge* today, for it is not relevant for the problems we are confronted with today. It forms a part, a study material, of the *history* of that subject. It is not itself a study material today.

Let me clarify this point further.

When we make an epistemological study of how man has advanced in his cognitive activities and organized his knowledge in diverse fields, we see that there are three processes at work: namely, cumulative, integrative and contiguous.

By the term "cumulative process" we mean that what we know today in any sphere of cognition is not something known just today, isolatedly, sporadically, as it is only; it is an accumulated product of a long process — which may be spread over many hundreds, even thousands of years. Man can know only bit by bit, gradually, and successively. But the knowledge at every step is added to that acquired up to that point of time. No positive knowledge once gained is ever lost in the history of mankind. It is therefore obvious that the present knowledge about something contains all that has been known by man thereabout till now.

Let us take a simple example. When a big building is constructed, all the separate bricks used for the purpose are permanently set there in the total structure. They may not be separately visible to the naked eye, but everybody knows that they are quite extant there in the true sense of the term Knowledge of anything is a totality like that. There is no need to know the ancient bit of information in it as a subject of knowledge as such. We may only want to know — what man had known about it at a particular point of history.

present body of knowledge which — although not clearly spelt out in the policy document — is evident from the forcible introduction of the outmoded subjects like Vedic Jyotish, Vedic Mathematics, Vastushastra, Yoga, etc. already in the formal educational curricula by the UGC fund baiting.

My contention is twofold: (1) None of the subjects referred to here originated in the Vedas or late-Vedic literature. The jyotish-tattva practised in India is of Graeco-Roman origin and came to be fully elaborated not until the 6th century A. D. from the time of Varahamihira. The arithmetic had begun to be developed since the Asokan period (2nd century B. C.) and algebra around the time of Aryabhatt in the late 5th century A.D. These subjects have been thoroughly studied in the historiography of Indian science and technology by several authors (although there is as yet no consensus among them about the time table and the exact level of development of the respective items) — some of whom have been referred to above.

(2) None of these subjects contain any useful information, which is not already known and need be learnt afresh by the students at present for the sake of accurate and up-to-date knowledge. Moreover, the jyotish-shastra or astrology is actually based on totally wrong information, all of which have been studied in detail, thoroughly examined and ultimately rejected by the scientific community long back in the light of the advancing frontiers of science.[33] Similar is the case with vastushastra, yoga, etc. Apart from some ancient magico-religious rites and assertions these two subjects can give a modem man no positive and useful information or insight in the respective areas concerned, namely, civil construction and human psychology.

A science policy, which does not condemn or criticize these trash but is formulated in the backdrop of encouragement to such well-known wrong and outworn prejudices, can lead to nothing good for the country.

It may be worthwhile here to look for the national as well as global ideological basis of these revivalist programmes. It

has been noted by several authors that this tendency to glorify the past has been strengthened in recent years by the various post-modernist schools of thought, which have directed their attack against the universality of the scientific tradition upheld since the Era of Enlightenment in post-medieval Europe. These schools of thought contend that the criteria of "objectivity", "rationality", "reality", "causality", etc are not so much basic to the theories of science as to the roots of western culture. Other cultures may have their own criteria to adjudge the value of a scientific theory in *terms* of the ideological and psychological services it renders to that cultural community. This is also defended in pretty colorful terms as the liberation of the oriental culture from the colonial aggression of the western culture, defence of the folk-beliefs in the face of the elitist dominance, "democratization from below", so on and so forth.

Let us give some examples.

Andrew Ross, a spokesman of this trend, believes that supporting the popular beliefs is a sign of this democratization, while demanding rigorous tests for these beliefs is sheer elitism. According to him, it is only when we attenuate the claims of empirical rationality and recognize "different ways of doing science, ways that downgrade methodology, experiment, and manufacturing in favour of local environments, cultural values, and principles of social justice" — can we begin to move towards true diversity of knowledge systems.

Similarly, Sandra Harding, another post-modernist, argues that modem science as it is present to us is far from a universal body of knowledge and is strictly a western "ethnoscience". There is a need to empathize with other cultures in a multicultural world, for which, she thinks, we have to give up the dream of the "one true science" and begin to live with a "borderland epistemology". By this she implies an epistemology that "values the distinctive understandings of nature that different cultures have resources to generate".[34]

A conservative lobby has been quick to pick up this call for decolonizing science, technology, as well as Vedic studies.

They are very much inspired by the logic that the local knowledge systems be subjected to the local analytical tools rather than to the western standards. They feel that the rigorous scientific methods and procedures being applied in the Indological studies often render results contrary to what they want the people to believe. With this "ethno-cultural" approach to ancient Indian wisdom it becomes easier to highlight its uniqueness and pertinence. It becomes easy for some such intellectuals even to defend the outworn brahminical strictures like burning of widow on the dead husband's pier, and to oppose the modernist view regarding remarriage of a widow.[35]

The irony of the attempt, however, is that it also comes first from a group of western scholars who have been engaged in building up an alternative to the synthetic, rational, universal and objective judgment of the world of nature and man. Thus the post-modernist theoreticians do not really help to "decolonize" scientific standards and cultural values but rather substitute some new and reactionary western post-modernist theses for the four-century-old well-tested scientific reason and heritage of the Enlightenment and transport them to the periphery to satisfy their local ethno-cultural sentiments.

VI

The policy in its other declarations asserts some things, which are clearly irrelevant or contrary to what the Government has been doing for the last few years. An example of this indulgence in irrelevant proclamation is found in its intentions to "mount a direct and sustained effort on the alleviation of poverty, enhancing livelihood security, removal of hunger and malnutrition, reduction of drudgery and regional imbalances, both rural and urban, and generation of employment", etc. Clearly, it is imposing the tasks of the Government in the arena of economics and development on to the science and technology regime. Science and technology has long created the scope to improve the living conditions of man in all aspects of life. But it is the policy of the governments and the line of development pursued, which ultimately decide whether these opportunities will be brought to the common

millions or be kept confined among the chosen elite. It depends neither on science and technology nor on the scientific community.

While since the 1980s the Union Government — led by whatsoever forces - has been pursuing the policy to discourage research in the universities, cleverly using the funding weapon, the present policy statement asserts to the contrary, namely, that it will "vigorously foster scientific research in universities and other academic, scientific and engineering institutions", and that "Government will make necessary budgetary commitments for higher education and science and technology". The present Government does not show the slightest sign that it will do so. It has planned to go on for speedier privatization in the fields of higher education and research, encouraged private universities and professional institutes. It has also recently decided to rename the UGC as the University Governing Commission and remodel its functions for controlling the statutory universities.

The new Science and Technology Policy-2003 talks of attracting "the brightest young persons to careers in science and technology" and "creating suitable employment opportunities for them" at that very moment when the official economic policy of the Government is to import all the necessary technology and consultancy from the west, obstruct the free exercise of research faculties, and virtually stop recruitment in the vacant academic and scientist posts, let alone creating new institutes and posts to attract the promising scientific talents who are going abroad in utter frustration.

The policy, in Section C: Strategy and Implementation Plan, declares: "A concerted strategy is necessary to infuse a new sense of dynamism in our science and technology institutions. The science departments, agencies and other academic institutions, including the universities i.e. the science and technology system as a whole, would be substantially strengthened, given full autonomy and flexibility, and de-bureaucratized." These words are pronounced at a lime when the Government has been actually undermining the entire science and technology education and research through the means of fund crunch, feehike, privatization, encouragement to capitation fee and donation based institutions, and so forth. We hear these words of autonomy and flexibility at a time when the apex bodies of

different research conducting organizations, like the UGC, ICHR, ICSSR, etc. have been reconstituted.

The real de-bureaucratization could start only when the socio-cultural ethos — handed down from the feudal legacy and left intact even by the earlier Nehru-policy — which directly or indirectly supports the existing administrative norms of control of research from above and the culture of bossism in the research institutions, could be put an end to. But the guruvadi (authoritarian) mentality of the feudal hierarchical tradition continues to prevail in the relations among the juniors and the seniors of the scientific community to one another and is reinforced by the Government through its various Hindutvavadi policies, including its reference to the ancient tradition. In this situation there can be no question of real democratization of the science and technology administrative system. In the actual performances of the Union Government too we have so far seen no desire to shift from the undemocratic and bureaucratic narrow gauge line.

VII

The science and technology policy of the Government — both in its policy statement and in its actual practices is going to take us backward against the progressive mainstream of science. It indicates which kind of education and research the Government will encourage and which they will discourage. Already in the field of history education and research they have started applying this policy even before it was made public. Standard textbooks written by well-known historians in strict conformity with science logic and archaeology have been withdrawn from the CBSE school curriculum. Concerted propaganda has been launched through various media including the Internet to highlight the so-called Vedic sciences, controvert the well-founded data on the Harappan civilization on the basis of even fabrication of data. Attempts have been afoot with huge government fund and backing to promote the realization of the mythical Vedic Sarasvati River in support of this usurpation of the Harappan civilization by the Vedic culture.[36] If this attempt succeeds in the case of history it will be extended to new areas.

We are at the threshold of a crossroads. The experiences of the human society till the last century have accumulated a vast store of knowledge and perceptions for us. If we fail to differentiate the lessons from the illusions and allow ourselves to be guided by empty demagogy it may ultimately cost us even the civilized existence. If, on the other hand, we may properly draw and evaluate the lessons that emerge from the history and the treasury of knowledge, and decide our future course of advance accordingly, we shall be able to hold fast to civilization as the true Homo sapiens. For this we have to ask the Government to reject the present bureaucratically formulated policy and hold nation-wide discussions and debates to give birth to a new effective and scientific science and technology policy. #

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Industrial Evolution in India—from Pre-Historic to Modern Age

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Industrial evolution in India has a long glorious past dating back as far as to the pre-historic age. Following the traditional break up, the history of India's civilisation is considered to have passed through three important phases, namely, the ancient period, the medieval period and the modern period. Starting from the Indus Valley Civilisation which originated around 3500 B.C., the ancient period is demarcated at 1206 A.D. when the rule of the Sultaniyat began. This initiated the medieval period which continued upto the death of Aurangzeb, the last powerful Mughal emperor in 1707 A.D. With the arrival of the British East India Company, on the plea of trade, by then, the modern age began which is still continuing. The first two periods are also known as the Hindu period and the Muslim period respectively. The modern period is composed of the British rule upto the country's independence in 1947 and the rule of the country's people since then. In each of these periods, industrialisation occupied distinct nature and characteristics. So it is necessary to go through the ages, down from the Indus Valley Civilisation, to understand the evolution of industrial progress in India. Since it is not easy, in terms of time and space, to make a detailed study of the same covering a period of more than 5500 years so far, we shall try to evolve a broad outline of the industrial history with emphasis on the special features of each stage. Although our main focus would be on the post-independence industrial progress, but to grasp it, the past scenario must be kept in mind. This will also re-establish the fact that we had a bright past in respect of industrial activity which nullifies the British claim that they had done everything for us.

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Ancient Period (3500 B.C. — 1206 A.D.)

This period saw many important civilisations grown up and flourished in our motherland of which the pioneer was the Indus Valley Civilisation spreaded over the period from B.C. 3500 to 1750. There were important accounts of the improved socio-economic life of the people there. Although this civilisation was mostly agricultural, trade also prospered dominated by handicrafts made in cottage industries. People were acquainted with ornaments made of metals like gold, silver, copper, bronze, faience, shell and pottery. Among the domestic uses, cloths were spun in hand-driven weaving machines. Toilet jars were made of ivory, metal, pottery and stone. The ladies were used to perfumes and cosmetics made domestically. Combs and razors were made of bronze. Kitchen utensils were made of pottery, stone, shell, faience, ivory and metal. Copper and bronze replaced stone later as the material for household implements. Chairs, bed steads and stools were used to decorate the drawing rooms. Charpais and stools were made of wood. People used lamps of copper, shell and pottery. There was some mining activity also. It is learnt that Ajmer might have supplied lead to the Indus valley. Silver was imported from Sumer. Raw materials necessary for industry were also imported. All of these indicate a self-styled, smooth and simple economy based mostly on the small scale and cottage industries with agriculture and trade being the leading occupations. This period could easily be marked as the dawn of industrialisation in the country.

Next emerged the Vedic Civilisation or the Aryan Age which lasted for about 500 years from B.C. 1500 to 1000. It bore the following important signs in respect of industrial advancement. Carpentry was an honoured profession. The carpenters did all sorts of work in wood including fashioned chariots of war and race, and carts for agriculture and transport. They also knew carved works of finer types. It may be considered as something like a wood revolution. Household utensils were made of metals like copper, bronze or iron. Along with these, earthen wares and wooden vessels were used for eating and drinking. Tannery works by using hides were well known. Skin bags were used for carrying goods. Women workers were also abundant in works of sewing, plaiting of mats from grass or reeds. These were done mostly in home and cottage industries.

There was no appreciable break in the economic life of the Vedic Aryans from the age of the Rig-Veda Samhita down to the age of the Brahmans. However, there was a more extensive knowledge and use of different kinds of metals. During the ages of the Upanishads and the Sutras, there were mentions of locally manufactured implements and vessels of copper, iron and stone and earthen wares. Golden spoons and brass gongs were used by the people. Silver was also known to them. Cloths worn were of various things like cotton, linen, woollen, silken and hempen. Spinning and weaving were the important daily occupations of the people.

Next followed the two almost contemporary religious awakenings—the Buddhism around 566 B.C. and the Jainism around 540 B.C. Then, due to lack of political unity, no single civilisation emerged. But the Buddhist and the Jaina books mentioned of 16 Mahajanapadas (small states) spreaded throughout the country from Kabul in the north-west to the Bay of Bengal in the east. Most of these were in Bihar, Uttar Pradesh and the central India. Bengal, Assam, Orissa, Sindhu and the far-southern India had no such state. Of these the most important and powerful were Koshal, Abanti, Batsa and Magadh. Among these Magadh earned the prominence. It was ruled by the four important dynasties of which the Maurya and the Gupta dynasties were significant as the Hindu civilisation reached the peaks then as per the accounts of the home and the foreign writers and the royal messengers. The Mahajanapadas heralded 'second urbanisation' after Harappa in the Ganga-Jamuna valley in India.

The Maurya dynasty had its rule over the period from B.C. 324 to 182. Two important documents were available on this period—the 'Indica' of Megasthenes, an ambassador from Babbylon, and the famous 'Arthashastra' of Kautilya, popularly known as Chanakya. According to these books, different branches of the economy were then run in a disciplined way under the state supervision. The Indica provided that there was state-managed agriculture fed by systematic irrigation. Industry, trade and mining were highly improved which yielded revenue to the government. Metals like gold, silver, copper, tin, iron etc. were in abundant use. People loved to wear ornaments. Artisans constituted the prestigious class of people in the society.

The Arthashastra made important additions. It confirmed

remarkable progress in the trade and industry. There were mentions of large number of arts, crafts and occupations. The Jatakas referred to the 18 standard handicrafts. The mining industry grew very important. Industries were localised. Villages and roads were named after the industries or the industrial occupations, like the weavers' lane. The towns had workshops and markets. Most importantly, there were guilds or nigams (of the medieval Europe's type) conducting the industrial works.

India then flourished through the guilds or the nigams of the artisans and the traders. The nigams were of two types—commercial and professional. Numerous artists and artisans joined the nigams as it was not possible for any single artist to compete with the nigams. Then the important nigams were of the artisans dealing with pottery, metal and wood or the carpenters. Clay industry was widely spreaded over. The chief objective of the nigams was to safeguard the interests of the artisans and the buyers. The kings used to invest in trade and commerce and so had interest to prosper the nigams. The nigams were also used to act as the bankers and the financiers to the artisans. The traders engaged in such things were all 'sresthin', the later generations of whom are known as the sheths in north-India and chettis in south-India. With the emergence of the money economy, banking as well as the money lending business was developed rapidly. Money circulation had widely increased in the post-Maurya period.

The artisans and traders had high reputation in the society. The Greek writers had high praise for the Indian artisans making handicrafts of wood, tusk, leather and metals and machineries and garments. The architectures and the sculptures were basically of professional merit. The town plans incorporated separate buildings for the artist nigams. Such a building was discovered by John Marshall. Indian textile industry was of high standard during the Maurya period. Indian textiles were widely preferred abroad. Kashi, Konkan, Banga and Mysore were the important centres of production. Silk textiles had also high demand. Many people were fed on the cotton textiles. Indian silks were exported to Rome.

Industries grew at those places where raw materials and skilled labours were in abundant supply. Magadh supplied iron in huge quantity to different factories. Mines of good quality copper were in Rajasthan and in south-India and salt depot was

in Punjab. The then prosperity of industry and trade is clear from the fact that the sales tax constituted an important source of revenue to the state. Different foreign forces invaded India before, during and after the Maurya dynasty (558 B.C. - 50 A.D.). Of these the Kushans and the Huns had settled in India. As China developed the silk production, it was brought to Iran and the Roman empire through the silk way which was under the control of the Kushans for which they collected huge revenue. They first introduced the gold coins, following the Roman type, around 78 A.D. Those were of very high standard.

The then industries could be classified into four broad groups (a) the state monopolies making weapons and brewing liquor; (b) state controlled industries including textiles, salt and jewellery manufactures; (c) state regulated small industries of craftsmen like goldsmiths, blacksmiths, weavers and dyers; and (d) establishments of the unregulated craftsmen like potters, basket makers etc. There were other industries, such as, of construction and of ship and boat building and the manufactures of carts and chariots. In fact, the artisans had efficiency in their production. Metal industry was also prosperous during the Maurya era. The Arthashastra mentioned of the different metal industries. Everyone, irrespective of men and women, used to wear ornaments. It was interesting that the prisons had factories worked by the penal labours. Helpless and purdah women were employed in the state spinning houses which turned out yarns of cotton, silk, wool and jute and manufactured cloths of all kinds, ropes, blankets and curtains. It is significant to note, which Kautilya maintained, that the state used to run a diversified economy actively, efficiently, prudently and profitably.

After Alexander's invasion, the Maurya kings set up close trade relations with the countries of West Asia and north Africa. Trade was mostly conducted by land and the sea routes. Trade relation was established with Rome during the first century B.C. China, Greece and Singhal also came under the trade links with India. Traders of these countries used to take luxury goods, muslins, spices and cotton textiles from India.

The Maurya period was followed by another glorious period ruled by the Gupta dynasty over the period A.D. 270 to 467. As this period ushered in an all round development in the arts, science and economy, it is renowned as the 'golden age' of the ancient India. Fa-hien, a Chinese traveller, provided important

account of this period. Since he came to India after visiting 30 other countries, he could easily compare and rate India's progress as the best one. He observed that apart from the pre-historic textile industry, cloths were also made of cotton, silk, wool, linen and barks of trees. The textiles were made of the finer and the coarser varieties. Benaras was an important centre of the cloth making.

According to Fa-hien, there were capitalistic methods of production and distribution emerged with the age-old domestic system. There was also an important intercourse with the outside world including the countries like China, central Asia Afganistan, Tibet, the countries of the far-east like Mongolia, Korea and Japan; the western countries like the Roman empire, the Arab, Persia and Greece; and the East Indies like Burma, the Malay Peninsula, Sumatra, Java, Borneo, Bali and Singhal etc.

But India faced the economic decay as its trade with Rome and China fell as the former was invaded by the Barbars while the latter developed the silk making technique. However, the gold coins provided its prestige. Besides, trade of the luxury items flourished. Also flourished the metal industry. The 'Iron Pillar' now standing by the side of the Kutub Minar in Delhi bears the mark.

The fall of the Gupta dynasty was followed by the appearance of several regional dynasties. The important of these in the north and the east India were the Huns in north India, Jashadharman at Mandashore in Malay, Sashanka in Bengal, Pushyabhuti at Thaneswar, Pal in Bengal, Sen in Bengal etc. Those in the south were the Chalukyas, Rashtrakut, Pallava and Chola. Harshavardhan was the prominent ruler of the Pushyabhuti dynasty at Thaneswar who ruled over the period between A.D. 606 and 647, during which Hiuen-Tsang, another noted Chinese scholar and traveller, came to India. He provided important account of the contemporary period's socio-economic situation. According to him, apart from agriculture, industry was another aspect of the economic life. Cottage industries including cotton textile, clay industry and metal industry were important. Boat industry was also very much developed. Cottage industries provided the necessities of life. Tamralipta (Tamluk) and Saptagram (Hooghly) were the important ports. Muslins and various plants were exported outside. Nepal, Bhutan and Tibet

had commercial links with Bengal. Since the 8th century, India's trade was captured by the Arabs and so, like of other parts of the country, Bengal's trade declined gradually.

Medieval Period (700 A.D. - 1707 A.D.)

This period comprised of the rules of the foreign forces which invaded India and then settled. The notable among those were the Sultani period or the Turkey-Afgan empire which ruled over the period from A.D. 1009 to 1526 and the Mughal empire which ruled over the period from A.D. 1526 to 1707. The Sultaniyat had important dynasties like the Ghory, Ibok, Balban, Khalji, Tughlak, Sayed and Lodi. Some regional powers like the Ellyas Sahi and the Hussain Sahi dynasties in Bengal and those ruled in the Bahmani and the Vijayanagar Kingdoms in the south also emerged. The consolidation of the Mughal empire was loosened after the death of Akbar, the greatest emperor of the country, famous mostly for his secular outlook and patronage to all the branches of arts, construction as well as economy. It led to the rise of the regional powers. The important among them were the Nizam dynasty in Hyderabad, Murshidkuli Khan and Alibardi Khan in Bengal, Sadat Khan and Safdar Jung in Ayodhya, Hyder Ali in Mysore, Shibaji and Shambhuji in Maharashtra, Peshwa dynasty in Maharashtra, Bhonsles of Berar, Gaekowad of Baroda, Sindhia of Gowalior, Holkar of Indore and Pubar of Dhar in Malaba. Such a long list of the regional forces indicates that political unity was weak during the middle age of the Indian history which disrupted economic prosperity. However, some famous tourists like Ibn Batuta, Marco Polo, Alberuni etc. visited the country during this period. Their accounts provided important information on the then economic life of the country.

The middle age had both the public and the private sector industries which were mostly traditional and hand-driven. Among the public enterprises, the notable were the embroidery works, gold works, silk works and furnitures. Then cotton industry was of prime importance with Varanasi, Agra, Jaunpur, Lukhnow and the then Bengal being the chief centres. Muslin of Dhaka was the world famous. Apart from the cotton works, Bengal also developed the silk works, the embroidery works and the dying industry. Then Lahore and Kashmir earned the

prominence in producing shawls and carpets. Kalico cloths were produced to satisfy the western demand. Berhampur, Ahmedabad and Agra flourished with the printed cotton products. Among the other things, Punjab and Uttar Pradesh became important centres of sugar production. Bihar produced salt-petres in abundance. Then India had improved technology in producing war equipments. Heavy cannons of iron and bronze could be produced domestically.

Towards the end of the Mughal period, some industries were developed as well as modernised by the foreign initiative. As for example, the cotton industry was modernised under the British and the Dutch influence. However, it was no denying that India, in general, lagged behind China and Europe in respect of technology. Moreover, towards the end of the Mughal period, there was anarchy in social life which caused the decay in economic and industrial activities.

So India had a long heritage of industrial activity dating back to the Indus Valley Civilisation. A study, down through the ages under different civilisations, dynasties and rulers, confirms its industrial prosperity. Some important points may be noted to characterise its industrial supremacy upto the arrival of the British rulers.

India developed preparation of silk from the silk worm, wool from the hilly ram and fly whisks, musk from the chamara deer and articles from the elephants' tusk. Manufacture of the leather goods was common from the Vedic times. Gujarat emerged as the largest centre of the dressed skins of different types (of goats, domestic and wild oxen, buffaloes etc.) and of the beautiful mats embroidered with gold. Sleeping mats and cushions were sold for ten and six silver marks apiece respectively. Another important industry was the pearl fisheries and the preparation of pearls for ornaments. Manufacture of textiles, a very old industry, was flourished in different places of the western and the central India in different periods as described by Marco Polo. Another old industry, developed during the Indus Valley Civilisation, was the stone cutting including the stone polishing. The art of working with the metals like iron, gold and silver was also very famous. Arts of the jewellers had the reputation. Industrial and commercial guilds played the important role in making economic progress. Besides, there were the capitalists' and the labours' partnerships which, as per the Smriti

Chandrika, dealt with trade, agriculture and crafts. The labour laws dealt with the wages, compensation and liabilities marked by equity and justice.

India had important trade links with Europe and many other countries of Asia notably Singhal, Burma, China, Japan, Nepal, Iran etc. India's exportables to Europe included calico, opium, cotton and muslin cloths, sugar, salt-petre, wax and different types of spices. On the other hand, its imports were comprised of the utensils of china clay, silver bars, horse, precious stones like diamonds, tusks, velvet and perfumed oils. With the arrival of Vasco-Da-Gama at the Calicut port in A.D. 1498, Portugese trade with India began to grow. The then existing mercantilist policy in Europe, which justified a country's wealth through trade and even plunder, if possible, of the other nations, induced them much in it. It lured other European nations like the Dutch, the French and the British to set up the East India Companies and begin trade with the Indian merchants. The British East India Company was established in A.D. 1600 which received monopoly right of trade in the East from Elizabeth I, the Queen. It set up its first trade centre at Surat in A.D. 1608 when captain Hawkins was granted the trade right by Jahangir, the Mughal emperor, under the recommendation of James I, the King of England. Later Sir Thomas Roe was successful in extending the right to other centres like Gujarat, Ahmedabad etc. Gradually the Company set up trade centres at Madras and Bombay. Finally, it was successful to set up trade centre in Bengal, which emerged with significant trade prospect during the Mughal regime, when Job Charnock was accorded permission by Shayesta Khan, under the instruction of Aurangzeb, the Mughal emperor, to build up a trade kuthi at Sutanati village, on the bank of the Hooghly river, near Calcutta in A.D. 1690. Bengal's prosperous products of the cotton textiles, muslins, silk and calico were their chief targets. By then the industrial revolution was almost complete in England which ensured huge quantities of mechanised productions and hence motivated them to find new markets, big in size, as was the then India. After the death of Aurangzeb in A.D. 1707, they consolidated their grip first over Bengal and gradually over India and, through numerous wars and agreements, ultimately became the ruler of the country. So A.D. 1707 has been chosen in our study as the beginning of the British period in India. This period had two distinct phases—the first

between A.D. 1757 (the Battle of Plassy) and 1857 (the Sipoy Mutiny) during which the Company rule was consilidated and got momentum; and the second between A.D. 1858 (the transfer of power from the Company to the Queen, or, in other words, the British Parliament which appointed a minister in charge of India, called the Viceroy, and Lord Canning was the first such man) and 1947 when India gained the independence.

Modern Period (1707 A.D. - still continuing)

It is true that the British helped to grow some sophisticated industries in India and carried out some needed diversification and modernisation of the existing industries with its capital, technology and the managerial efficiency. But their propaganda was never true that there was no major industry in India prior to their arrival. Rather it can not be denied that India had a strong industrial base which was, however, of indigenous character depending mostly on domestic resources. Indian industries occupied the following features during the British rule.

It is true that large scale industry, based on the factory system, came to India as the by-product of the British rule. Till 1860's, attempts were made from time to time to introduce the new manufactures and the modern methods into a scene of traditional handicrafts and domestic production, mostly by the East India Company or the private British merchants, both being traders primarily. Hence a commercial revolution was expected to be accompanied by an industrial revolution within the next 50 to 70 years. But this was not the case in reality, rather machines and machine-made products were imported from the Great Britain in ever increasing quantities with only a handful of the specialised industries being built up here. Moreover, this was at the cost of the indigeneous industries which were destroyed in the process. As a result, possibility of an industrial revolution was shifted from India. While the Marxists accounted this by the exploitation theory, others explained it by the absence of social and psychological skill which retarded its economic progress.

Development of modern industries : Indigo : One cannot, however, deny that some modern industries were developed by the British. In the chronology of such industries came first the indigo industry. The Company's search for a substitute to India's

calico combined with the private British capital flourished this industry, mostly in Bengal. In the Bengal Presidency, there were 899 factories covering 30 to 40 lakh bighas of land and investing 2 crores of rupees annually. The invention of the synthetic dye in 1897 dealt a death blow to this industry.

Tea : What indigo lost, tea gained. When the Company's China monopoly was abolished in 1833, it turned to India to the possibilities of tea production. The first garden in the country was reported by Robert Bruce in Assam in 1823. Captain Jenkins reported of the same in Darjeeling on 17th May, 1833. In order to grow tea on a commercial basis, The Assam Company was founded by the London merchants on 12th February, 1839. Dwarkanath Tagore's Carr, Tagore and Company formed the Bengal Tea Association for the same purpose. These two were merged under the name the Assam Tea Company, the only company upto 1850. But between 1859-65, 20 such companies were registered in London and Calcutta. Besides, there were many unregistered private gardens. The Managing Agency System had a near monopoly in tea production and trade, although a slight shift of control from the European to the Indian hands was seen in Bengal. Development of the Assam-Bengal Railway and the Chittagung Port gave a fillip to this business.

Jute : Jute manufacture was mainly fed on the imported capital and remained a near British monopoly. It was concentrated on the banks of the Hooghly river in Bengal. The first jute spinning mill was set up at Rishra in the Hooghly district in 1855. The first power driven looms began to work at Baranagar near Calcutta in 1859. The Indian Jute Mills Association was set up in 1884 to take advantage of the boom in production and sale. Bengal's natural monopoly in raw jute production was fully exploited by the adequate British capital.

Cotton : Jute and cotton industries, organised on the factory basis, were contemporary, but while the British monopolised the former, the Bengalees held the latter. In fact, cotton production had been a great art in India from time immemorial. But Bombay and Ahmedabad became the first centres of modern cotton industry in the 1860's, much after the development of Lancashire in England around 1750's. Development of railway in the 1850's also contributed to its expansion later. By 1890, the number of cotton mills in the country rose to 137 and Bombay, with 94 mills, was the leader in this respect.

Steel and Coal : Iron and coal industries paved way for the industrial revolution in England. But their absence in India hindered the growth of modern industries here during the entire 19th century. All the Indian attempts to produce steel were not successful during that century. As a result, the Indian railways, the textile mills etc. had to import from Britain all the iron and steel and machineries needed. Moreover, unlike England, India suffered long for the lack of adequate production of high grade coal. There was only one mine at work in 1840. The East Indian Railways, however, gave an impetus to the coal industry in 1921.

The Tata Iron and Steel Company (TISCO) was registered in August, 1907 which established its works at Sakchi (the town renamed as Jamshedpur after its founder Jamshedji Tata) in Bihar in 1908. The Indian Iron and Steel Company (IISCO) was set up at Hirapur in Bengal in 1918. The United Steel Corporation of Asia was registered in 1921. A number of other iron and steel companies came into existence after the world war I.

Paper : Production of the machine made paper dates back to 1970 when the Bally Mills on the bank of the Hooghly river was established. Then followed the Titagarh Paper Mill in 1882. The Bengal Paper Mill was set up in 1891 and the Imperial Mill was set up in 1893-94. All of these were in Bengal. But the industry was taking root in Lukhnow by 1879 and in Poona by 1887. Before the independence, there were 16 paper mills in the country.

Tanning : The modern tanning industry was started late although there was no lack of hides and skins in India. The Government Harness and Saddlery Factory was set up at Kanpur in 1860 from which superior leather began to be turned out, although with the help of the imported chemicals. The Madras government provided the promotional measures to this industry during 1903-11, as a result of which chrome tanning became possible.

Sugar : In sugar production there existed the old Indian method for a long past. The European methods of sugar refinery were introduced in India by the mid-19th century. There were 145 sugar industries in the country before the 2nd world war. Before independence, the country became self-sufficient in sugar and hence was capable to export.

Glass : This was totally a new production as it was not known

before the European venture. Several glass factories using updated production process came to be established in the last decade of the 19th century. By 1945, there were 96 glass factories throughout the country.

Cement : It is also a relatively new item of production as the first portland cement factory was set up near Madras in 1904. Three other factories came into being in 1912-13 at Porbandar (Gujarat), Katni (Madhya Pradesh) and Burudi (Rajasthan), although those together could produce even less than 1000 tonnes a year. The organisation of the industry improved with the amalgamation, in 1936, of the ten principal producers into the Associated Cement Companies (ACC) of India Ltd. As a result, on the eve of the independence, production of cement in India exceeded 20 lakh tonnes a year.

Match : The first match factory in the country was set up at Ahmedabad in 1985. The industry consisted of many small and a few big firms at the time of independence.

Chemical : Hardly there was any factory in the country before the first world war. Although the number of factories increased appreciably between 1931 and 1939, the industry remained weak as most of the firms were small and had problems in respect of purchase of raw materials and fuel.

Engineering : In the country, modern engineering methods were introduced in connection with the construction of roads, bridges and railways in the 19th century. A number of steel fabricating plants came to be established in the vicinity of the iron and steel plants specially in and around Jamshedpur. As Howrah also localised numerous small engineering plants, it came to be called the Sheffield of India.

Plan Period : When the British left India, its industrial field was almost in a doldrum. There was no systematic policy of industrial progress in the country although some modern factories grew up mostly during the second half of their rule. Unorganised agriculture was one of the many reasons which could not feed up industrial development. Hence there needed a consistently followed planned programme of industrialisation so that the country could develop a strong industrial base and achieve economic prosperity. On this objective, the country embarked on economic planning in 1951 and as strategy, the five-year planning process was chosen. Since then the country has, so far, completed nine five-year plans and has introduced

the tenth one in 2002. The plans did not have uniform strategy in respect of industrialisation—some put more emphasis on it, some less. Moreover, there was a controversy on building up large scale or small scale industries.

In this background, industrial progress during the first fifty years of the independent India may be reviewed. A plan-wise discussion in this regard would be helpful to identify the progress periodically. At the time of independence, India was basically an agricultural country having some agri-based industries like jute, cotton textile and sugar. The process of industrialisation in free India began with announcing the Industrial Policy Resolution of 1948 which evolved the idea of a controlled mixed economy. It classified the industries as (a) state monopoly comprising the three industries, namely, defence equipments, atomic power (research and development), and ownership and control of the railways; (b) state controlled sector including mining, iron and steel, aircraft manufacturing, ship building, mineral oil and telephone, telegraph and radio equipments; (c) state controlled and regularised sector consisting of sugar, cotton and silk products, cement, paper, salt, equipments etc.; (d) management of the government-run industries, and (e) management of the state-run industries. Besides, there were provisions to control the management of the private-run industries. In 1951, the Industries (development and regulation) Act, 1951 was passed to ease the licence system. The idea of nationalisation was mooted although its implementation was deferred for the next ten years.

First Plan : This plan had a meagre allocation of Rs. 293 crore on the industrial sector. Besides, the private sector also spent Rs. 233 crore to develop 42 large scale industries. As a result, there were enhanced production of cotton textiles, cement, paper and paper based items and bi-cycles etc. Moreover, new industries like oil refinery, ship building, railway wagons, penicillin etc. were developed. But, above all, annual industrial growth was surprising to reach an 8 per cent level.

Second Plan : The second plan (1956-61), based on the Mahalanobis model, aimed at an ambitious programme of industrial growth with the chief objective being to make and expand the industrial base. The said model was to develop the basic and heavy industries to facilitate production of capital and engineering products as the key to future prosperity. This plan

was complemented by the Industrial Policy Resolution of 1956 which kept as many as 17 industries under the government monopoly, and the new import policy of 1957 which induced capital imports to benefit industrialisation in the country. This plan massively increased the monetary allocation on the industries, to be Rs. 1,810 crore, which was 27.1 per cent of the total. But despite all these, industrial growth rate achieved during this plan was only 7 per cent, which was even lower than that of the first plan. There was, however, some notable achievements; (a) three new steel plants at Durgapur, Bhilai and Rourkela were set up; (b) production capacity of the Mysore Steel Plant was raised; (c) input industries like coal, fertiliser, heavy engineering goods, heavy electricals etc. were developed; (d) drive to modernise industries like jute, cotton and sugar was undertaken.

Third Plan : The third plan (1961-66) put major emphasis on promoting the infrastructure like power and transport. Besides, there was stress on the development of the sectors like steel, chemical, mechanical, power and fuel so that the country would not import those after 15 years. It allocated Rs. 2,720 crore on industrial development. The industrial growth rate achieved during this plan was 7.6 per cent, which was, although, higher than the second plan, still lower than the first plan. However, during this plan, the giant public sector ventures like the HEC, MAMC and BHEL were completed.

Next followed the three annual plans in the consecutive years of 1966-67, 1967-68 and 1968-69 during which the country achieved the 'green revolution' to have immensely benefited the industrial sector.

Fourth Plan : After this brief plan holiday, the country returned to the path of five-year plans and began the fourth plan. Although financial allocation to the industrial field increased to Rs. 5,338 crore, this plan could not cease the industrial deceleration. As a result, the industrial sector registered a very low growth of 3.9 per cent, which was, in fact, the lowest among all the plans completed so far.

Fifth Plan : Then came the fifth plan (1974-79) whose going was, however, interruped twice due to change of governments at the centre. The original plan had the objectives of spreading the core sector industries, increasing exports of the consumer goods industries, reducing production of the unimportant goods

and expanding the small scale sector. Rs. 10,201 crore was allocated to fulfil these. It was 25.9 per cent of the total plan allocation. Although the industrial sector achieved a 5 per cent growth, larger than the previous plan, there existed a big gap between the targets and the achievements in respect of industries like steel, cement, sugar, aluminium, paper, newsprint, nitrogen fertiliser, phosphate fertiliser etc.

Sixth Plan : Hence the sixth plan (1980-85) stressed on full utilisation of the production capacities so that all types of the industries can reach their growth targets. For the purpose, Rs. 22,000 crore was provided which constituted 22.8 per cent of the total. During this plan, some of the industires like petroleum, passenger cars, two wheelers, T.V. sets etc. prospered, but the heavy industries like coal, cement, iron, sugar, railway wagons, cotton textiles etc. lagged behind. As the 'sunrise industry', electronic sector including computer softwares advanced significantly. As an overall effect, industrial sector grew by 5.5 per cent.

Seventh Plan : On a relatively happy note of the economy, the seventh plan (1985-90) was undertaken to evolve an integrated policy towards self-reliance in the strategic fields, opening up of the job avenues for the skilled and trained manpower and growth of the sunrise industries as well as the industries with huge potential for the domestic market and export. Although the relative allocation to this sector fell to only 12.5 per cent which, in effect, was of Rs. 22,460 crore, this plan achieved much improved growth rate of 7.5 per cent for the industries, 2 per cent larger than the previous one. This was largely due to improved performance of the mining, manufacturing and electricity generating sectors.

Then came the country's unprecedented economic crisis resulting from the deep depression world wide and the huge trade deficit leading to only a meagre foreign exchange reserves. The gulf war had worsened the situation. It needed to halt the planning process for the two years to overhaul the economy through a change in industrial outlook. Accordingly the new industrial policy was announced on 24th July, 1991 which provided some path breaking changes, particularly in respect of the public sector industries, as follows : (a) The licensing system was abolished excepting for the 18 industries of which 8 were kept under the government control. These included defence

equipments, atomic energy, coal and lignite, mineral oil, mining of iron and copper and railway transport. (b) Foreign participation in Indian industries (with full export potential) was raised to 51 per cent from 40 per cent. (c) exit policy was introduced for the sick and losing concerns. All of these were expected to induce competitiveness in the industrial field. The industrial policy was followed by a new trade policy which liberalised foreign trade through removing the restrictions in the form of tariffs, duties and quotas.

Eighth Plan : The eighth plan (1992-97) was launched to strengthen the economy's reform process with a clear edge towards privatisation. It made the eighth plan indicative in nature with the major thrust being given on the market forces. It had the following features. (a) Government's role was reduced, in terms of investment, from 26 per cent of the seventh plan to 23.6 per cent. (b) Leading role was given to the private sector in respect of industrial recovery. (c) Strong urge was there to imbibe competitiveness and efficiency in the economic operations. (d) For future growth, the sectors with comparative advantage would be given priority. Under this plan, industrial sector received Rs. 40,759 crore although 80 per cent of it could actually be spent. However, the sector, as a whole, performed satisfactorily in this plan and grew by an encouraging rate of 8 per cent.

Ninth Plan : The ninth plan (1997-2002) aimed at massive development of the infrastructures like energy, transport, irrigation and flood control, communications and science and technology. Besides, improvement of the social sector including health, education, water supply and sanitation was also emphasized. The financial allocation for this was enormous to the extent of Rs. 68,736 crore. Although the manufacturing sector grew by 3.9 per cent, the electricity, gas and water supply by 6.5 per cent and the construction by 6.8 per cent, the overall industrial growth during this plan was subdued mostly due to recession—both in domestic and world markets. Signs of industrial recovery were, however, there towards the concluding phase of the ninth plan.

Tenth Plan : Beginning on 1st April, 2002, this plan has no clear cut target of industrial growth. It aims to accelerate the economy's growth rate to reach 8 per cent for which both of public and private sector industrial units need to improve efficiency.

The ICOR also needs to be lowered appreciably from its present level of 4.0.

The entire above discussion may now be summed up in the following table which shows serious inconsistency in case of industrial performance in India.

Table-I
Planwise Industrial Progress

Plan	Financial Allocation (in Rs. crore)	Overall Rate of Growth (in per cent per year)
First Plan (1951-56)	293	8.0
Second Plan (1956-61)	1,810	7.0
Third Plan (1961-66)	2,720	7.6
Fourth Plan (1969-74)	5,338	3.9
Fifth Plan (original, 1974-79)	10,201	5.0
Sixth Plan (1980-85)	22,200	5.5
Seventh Plan (1985-90)	22,460	7.5
Eighth Plan (1992-97)	40,759	8.0
Ninth Plan (1997-02)	68,736	5.0 (expectedly)

Source : Books on Indian Economy as referred to later.

The fluctuating industrial progress in the country may also be understood if we break up the entire post-independence scenario into four distinguishing phases. The first phase is comprised of the fifteen years between 1950-51 and 1965-66 during which industries were organised and expanded to yield substantial progress. During this phase, the country put major emphasis on the heavy industries but at the cost of large scale imports resulting in severe foreign dependence and huge deficit spending to crop up awful inflation. The second phase covers the years between 1966-67 and 1979-80 when depression caused the slump in industrial activities. This phase marked the development of the consumer goods industries as a follow up of the import substitution measures, although, through still borrowing the foreign technology. But the initiative was lost due to market limitations. The years between 1980-81 and 1996-97 can be taken to form the third phase which marked the

industrial recovery. The fourth phase, which began in 1997-98 and is still continuing, faces the industrial recession again to accrue low annual growth.

The following table will clearly reveal the industrial scenario in different phases.

Table-II
Growth Rate of Different Types of Industries (in per cent)

Industry	1st Phase (1950-51 to 1965-66)	2nd Phase (1966-67 to 1979-80)	3rd Phase (1980-81 to 1996-97)	4th Phase (1997-98 & onwards)
Basic	11.0	5.9	8.8	6.5
Secondary	5.7	4.5	6.3	5.2
Capital Goods	15.4	6.7	6.1	8.1
Consumer Goods	4.7	5.6	5.3	5.7
Durable	11.5	10.8	14.4	7.8
Non-Durable	4.2	5.0	4.0	5.2
Total	8.0	5.7	7.0	5.0

Source : Books on Indian Economy as referred to later.

Performance of the Indian industries may now be considered in an overall perspective over the last fifty years. During this period, industry grew by a modest rate of 6 per cent a year. The rate of industrialisation, measured in terms of the industrial contribution in GDP, increased almost double, from 16.1 per cent in 1950-51 to 31.4 per cent in 1997-98. Growth of the public sector has been enormous which is now constituted of the 236 units involving a massive investment of Rs. 2,02,022 crore. Both in terms of the share in GDP and the value added, industrial base is strengthened over time, mostly because of the large scale modernisation drive since 1980's to foster industrial self-reliance.

But the industrial sector has also developed some serious weaknesses. Considering the nature of the goods produced, industrial structure in India is still thought to be backward. The high capital intensity and the low labour productivity have intensified the problem. This is more so for the public sector units. Employment elasticity (in terms of output) has really been meagre and falling over time. As a result, industrial sector has

registered a low employment rate which is only 1.55 per cent when the population growth rate is 2.1 per cent a year. A few big industrial houses have been further expanded to give rise to monopoly concentration of economic power, The anti-monopoly provisions of the 1970's like the MRTP Act and the FERA did not effectively come in the way. Failure to make the full capacity utilisation has been common in the industries. In fact, on an average, 17 per cent of the industries have failed to utilise even 50 per cent of their rated capacities in any year over time. Both of the public and the private sector industries are responsible. In fact, such utilisation was only of 65 per cent in TISCO, a private sector steel plant, and 52 per cent in IISCO, a public sector steel plant. Like the underutilisation, industrial sickness has also been very common in India. By 1997-98, about 2.37 lakh units had become sick. Moreover, there were the non-viable units. In the respective category were 89 per cent of the small units and 49 per cent of the other units. Regional imbalance has been another major area of concern. It is alleged that policies of both of the central government and the banks coupled with the locational advantage have favoured more industrialisation in the western and the southern states while the eastern states with significant comparative advantage in respect of coal and steel have been lagging.

As for remedial measures, problems of the major industries like iron and steel, cement, engineering, textile, sugar and jute are needed to be properly identified. Such industries must be cared for and their problems must be redressed in time if India wants to be reckoned as a big industrial power.

Besides, small scale industrial units also need to be properly nourished. It is worth mentioning that such industries account for a commendable position in the economy in terms of any aspect like value added, employment or exportability. Upto 1996-97 there were 28,60,000 small scale industrial units (SSI units) producing goods worth Rs. 4,12,636 crore and providing employment to 160 lakhs of people. Of its output, goods worth Rs. 39,249 crore were exported. Apart from such immense contribution, those are also helpful to reduce economic inequality as well as to remove regional disparity. Moreover, they involve lesser industrial dispute, are eco-friendly in nature and are easily organised in respect of capital and skill. Still the SSI units are not adequately grown because of the problems in respect of

availability of finance and particularly bank credit, supply of raw materials, machineries and other equipments. Marketing has also been a tardy affair in case of this industry. All of these have made the SSI units running with underutilised capacity. Here lies the reason that they are more prone to being sick. In India, about 3 lakh units have failed to be viable mostly because of the bureaucratic lethargy and the banking apathy. The ongoing reform process has given a chance to their survival if the government, after divesting of responsibility in respect of the large scale industries, concentrates on them to reap more of the above said benefits to the economy's betterment.

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History of Botany

B. MAJUMDER*

During the Neolithic period, there were men, who were capable to survive on earth by hunting and gathering essential foods. Hunting- gathering was sustainable methods to those people. They tried best to improve it. The process continued along with the invention of newer technology of stone tools and the other minor metallic usages. The gradual improvement of the newer technology invented gave an assurance of better prospects of life.

Different types of plant materials were collected both above as well as from the underground parts. They were accustomed to search and use different plants all around. The familiarity of plants were helpful to them.

The records of these plants are available from the cave study and on coprolites of the ancient people. The scientist collected many information from the fragmented plant parts, pollen, phytolith etc. These were of vital importance to the archeologist for determination of the age at which these plant parts were consumed. Similar results have been obtained from different countries including India.

Neolithic life

The technology with its diverse facets had developed gradually. In the ancient times, men had to face odds and adverse environments of life. Through evolution a man (*Homo sapiens*) became physically adopted to the earth and experienced technologically. They could invent tools and equipments for their survival.

During the neolithic ages, the stone implements were sharpened and polished types of tools were made. They utilised stone tools in their agricultural activities. They knew the use of fire and burnt the forest for cultivation and settlements. Homes were made with the available stones, plants and soils.

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The prehistoric hunter-gathering men could sustained their lives under adverse environments. Gradually they followed the agricultural practices on different crops, and domesticated animals. It gave then a better and strong foothold in the diverse ecological conditions for higher cultural life.

The agricultural and horticultural knowledge disseminated in different directions. The agricultural practices improved along with the cultivation of barley, wheat, bean, lentil, peas, flax, almond and fig. All these agro-botanically important plants had changed their life style of ancient men. They gained impetus for further new cultures in the future. Although these ancient people did not know the science of the crop plants but utilised their knowledge and technology that gathered through ages. Society and technology was improved day by day. Thereby they gained more security in daily life.

Indus valley civilization

A very distinct and advanced civilization was discovered in India by Cunningham (1875) and later by Marshall (1924). This was from excavated site at Mahenjodaro, Chanudaro, Lothal and Kalibangan. The evidences those were recorded from these sites were carbonised grain of wheat, rice and barley. All these cereals and social structure found there gave a strong support of a highly civilised society. These people had a good knowledge on the plants around their home.

The materials obtained or collected were analysed after the radiocarbon (c^{14}) study. Apart from this the pollen analysis, coprolite and phytolith study strongly supported that the age of indus valley civilization was from the 2500 BC - 1200 BC.

The people lived there with settled agricultural system and had acquired the knowledge on the domestication of plants and animals (Zohary and Hopp-1988). At the sane tine they collected wild grains, fruits and tubers for their livelihood. People tried to understand the trees and herbs around, and sooner they come in close association with plants, and dependent on it for their food, fuel and fodder. At the same time on ailment they get medical help from the plants. It is conclusive that they cultivated cotton for everyday use. Historian Allchin (1980) comments that such advanced all around civilization might have its antecedents to earlier one.

Age of Ramayana and Mahabharata

The age of Ramayana and Mahabharata is supposed to be in the period of 1200 BC-1000 BC. The plants grown around in this period were studied thoroughly. The people selected many plants which they thought useful. The importance of the plants had rested on the yield of foods fodder, fuel and medicinal properties. Because it meets the immediate need of the people.

The name of the plants were popularly known and could be recognised easily. Some of the plants mentioned in the epic Ramayana were, Arjuna (*Terminalia arjuna*), Kimsuka (*Butea monosperma*), Kadamba (*Anthocephalous kadamba*). It is well known that Sita was confined in the forest area of Ashoka (*Saraca asoca*).

Another story which is very popular to the Indian people is the search of a medicinal plant - Visalya karani (Tridex procumbent). When Lakshana was injured in the war against Ravana, Hanuman was requested to bring this medicinal plant Visalya Karani from mountain top. Hanuman could not identify the plant so he uprooted the whole mountain and brought it near the patient. This story indicates that the people of that age was conversant with the medicinal plant Visyalkarani and its curative value on the cardiac and pulmonary diseases.

Similar many names of plants are mentioned in the epic Mahabharata, specifically in the Indraprastha, Gandamardhan forest and Dawita vana. The plants mentioned there are Bilva (Aegle marmelos), Karabira (Nerium indicum), Parijata (Nyctanthas arbor-tristis) etc.

The story of the Jatugriha daha is well known to Indian people. It was made of lacca and other highly inflamable materials. Lacca was produced by the insects on a specific plant Kusum. The insect is known as Lacca (Tachardia lacca). Therefore it is expected that this relation between animal and plant interaction was well known at that age. They collected lacca and built house for dwelling purpose.

Charak and medicinal plants

Charaka was the court physician of the king Kanishka at Peshawar. It is round about first century AD. He tried his best to introduce the basic principle of pharmacology in the Indian

arena. The number of plants were identified as a valuable medicinal properties for their specific curative characters.

The Charak sanghita has mentioned many names of plants having medicinal properties. Some of the medicinal plants identified by charak are mentioned here. Vasak (*Adhatoda vasica*) for pulmonary congestion, Bilva (*Aegle marmelos*) for conspitation, Amlaki (*Emblica officinalis*) a rich source of vitamins and used as a tonic, Somraja (*Psorelia corylifolia L*) etc.

All these records are examples of matured knowledge on tne botanical plants available all around. The studies specially on the medicinal plants had received a good attention. It attained a marvellous achievements out of their painful persuation of knowledge.

The Atharvaveda carries the vital information on the ancient medical treatments. This vedic system was an authority and primary importance for the treatment of Indian people in the past ages. This practice was confined within the 'Baidya doctors' of the Indian continents. It is not lost today, but it continues in our country. At present modernization is wanted in this system to revitalise the old ideas in the light of modern scientific knowledge.

Botany under the Muslim ruler

With the arrival of the Afgan muslim ruler in India, there was a change in the political senario. Cultural impact was significant. The moslems who came to India from outside did not bring a new technology to be added in India. Most of the royal people was a class by itself. Others were converts from the hindu. There was tendency to exploit the Indian people politically.

The interaction of the afgan culture had a great effect on the existing thoughts and ways of life. Still amidst the socioeconomic, and religious differences, people lived mostly as a good neighbours. Their ambition tended to harmonise the philosophical unity, between them. Surely there was newer admixture of art and culture.

Later the Moghul people came to India. Babar, the moghul prince was a poet, tactful military personal. He mentioned a number of fruit plants in his memoirs (Leyden and Erskin 1876). These were mango (Mukherjee 1953), banana, muskmelon, jack

fruit etc. Humayun was a man of erudite scholar. Akbar the great moghul, conquered a great part of India. His curiosity for knowledge and tolerance to varied religious belief made him an attractive person of the time. During his long reign from 1556. 1605, Akbar meet a varied types of people with different faiths and inventions.

European Jesuits came and had discussed with Akbar on religion, political and industrial change in Europe after the renaissence. He was persuaded by these theologians, scholars and talents. His aesthetic sense of art and biology invoked him to establish the different moghul gardens in India, which are of important till to day.

Akbar took interest in the study of Biology, and ordered to teach botany and zoology to the students of Madrassa (Smith 1958) · But did not like to unearth coal from the geological strata, although, European people had shown samples of coal brought to him from England.

Jhangir (1605-1627) had an European tutor who created his interest in the biological sciences. He was a lover of natural beauty and arts. His studies on plants and animals still draw attention. In short it can be mentioned that horticultural flowers were cultivated for perfumes. Tobacco was cultivated by royal personalities for nancotics.

Portuguese arrival

Vasco de Gama arrived at Calicut in 1498. Soon thereafter, they occupied Calicut, Cochin and Cannanore. Later the Governor who cane to India was Alfonso de Albmquerque. He was very ambitious person. He tried to establish a kingdom on the Western part of India. Henceforth many portuguese people migrated to India for trade and commerce. There were physicians, craftsmen, and scholars of diverse subjects.

These people first tried to influence the emperor Akbar. When He requested the Portuguese people to send a theologian to enlighten him on the christan philosophy. Then Aquaviva and Monserrate met him.

Akbar gave permission to establish fort and trading centres on the coastal India. It was in the year 1580. Akbar had an intellectual curiosity and for that the contact of the European people and the Mougul court was possible.

The scientifically trained persons of Portugal carried different wild and cultivated plants from mesoamerica to India. These introduced plants were grown in the occupied territory of the portuguese. Some introduced plants (Hutchinson 1976) are now very popular to the Indian people. These are like *Mirabilis jalapa*, (Sandhya Malati) papaya etc. (Table - 2).

There were biologist amongst them who studied the flora and fauna of the western coast of India. These publications of the portuguese people were very important in the context of the Indian floristic study. The book of the botanist Garcio de orto was very basic and important even, to day. Apart from these, they published many information on the Indian ports, Indian society, grammar of Bengali language, and other languages were of historically important (Table 2)

In short it can be mentioned that the interaction of the portuguese people to the Indian people were of cultural and scientific value for the development of the newer age in India. It is an interaction of the renaissance people of Europe and local people of India in the 15th, 16th and 17th century. Botanical science was developed in India by Portuguese before the arrival of English people.

Impact of European people on Botanical studies

East India Company came to India after its royal approval on the 31.12.1600. The Company came to trade between England and India. Soon after the battle of Plassey (1757) the company came to power and wanted to explore the natural resources of this country. The company appointed sir William Jones, a judge in the Supreme Court at Calcutta. Jones established the Asiatic society (1784). Here valuable works were done on the science and culture of this country and adjoining Asia as a whole.

William Carey (1761-1834). He was a dedicated elite person of the eighteened century India. His all effort was to propagate the missonary programme on the Indian soil. He was an emblem of renaissence. He came to Calcutta in the year 1793. Nine years later than sir William Jones.

He collected different plants of horticultural interest and grown in a garden at Serampore (1808). His life long effort was to develop horticultural plants at Alipore. He developed there an Agri- horticultural society (1820), where different flower and

fruit plants were grown for scientific study. He made another agricultural farm at Madnabati, where he cultivated fruits and agricultural plants to study their biology in general. The museum he made was of paramount importance. He was a great teacher and a guide of botany in those days.

He had great interest in the Botanical field and to communicate those thoughts amongst the fellow people around the Serampore. Not only this, but his search for flora around the vicinity of the area had helped to detect new species of *Careya harbecea*, *C. arborea*, *C. sphoerica*. It records his love for plant study. This was completely absent in those days in the Bengal at large.

The teaching of Botany was started in the college of Serampore during the period of his stay at the city. He was regarded as a good teacher of biology, at that time.

J.C. Marshman (1794-1877) a Junior associate of William Carey followed his foot print and took a great venture to develop his unfinished work at Serampore, Bengal. Principally he was a teacher and an editor, wrote books on biology in the early colonial period.

Forest research in India

In ancient times the forest was respected by the people. Forest was termed as "Aranya" and "Maha-Aranya" according to the size of the area. People studied the plants with their limited knowledge. The study of the forest, was improved with the arrival of European people, both Portuguese and the English.

The english merchants had to travel a long distance on sea route from England to India. Their vessel was wrecked in the long journey, so they searched for good salt water tolerant wood from the forests of India. The teak wood (*Tectona grandis*) was highly favourite to them. Apart from this hard wood was essential for them to prepare guns and the railway slipper.

For commerce and territorial conquest the english people tried to acquire more knowledge on the forests. They established the Indian Forest Department (1864) and "Forest Research Institute" at Derhadoon in the year 1878. Again attempt was made to grow teak plants in the Botanical gardens of India.

Scientific studies on the forest plants had accumulated information on the taxonomy, physiology, pest and diseases of

the plants. Botanical studies revealed many important characters of wood like the strength, its density and resistance to adverse environments which were of primary importance. Apart from this they searched for drugs available in the forest plants. Botanical studies are continued till to day in this institution, with the above mentioned programmes.

During the long period of 1757 - 1957 there was a change in the population structure of the country. High demand for fuel, domestic appliances, caused the denudation of hills in India. The demand is growing from year to year. Forest research thus has received a new impetus for aforestation and better management. More Botanical research on forest plants are needed today than before.

Taxonomy of plant e is a problem

Since time immemorial people could not classify the plant kingdom properly. There were many efforts to do the same. In the classical books of India, plants are mentioned as Lata, Gulma', 'Aryanya' and 'Maha-aranya'.

Local plants growing around were identified in the regional language. In the modern times on critical study it was observed that anomalies are there in naming the plants. Therefore during the 17th century to 19th century the European scientist tried to identify the plants in the light of modern science. A species is considered here as a basic taxonomic unit. Then there are different categories in the ascending order : genera, tribes, class and phyla.

Modern taxonomy has considered a species as a basic unit or taxon in biological classification. The present day taxonomy is followed according to the binomial nomenclature as laid by Linnaeus (1707-78).

The taxonomic problem of plants in India was in a critical situation. Under such condition the Europeans came and took up the problem of plant nomenclature. In the year 1787 Col. Kyd was appointed as a superintendent of newly founded the Royal Botanical Garden at shibpur.

The object of the garden was to grow trees and plants which are essential for their survival. They tried tick, tea, cinchona and others. It was William Roxberg who came next in the year 1793.

Different scientist came to work at Shibpur, they were Buchanon Hamilton (1815), Nathaniel Wallich (1816-1846), W.

Griffith (1842), J. D. Hooker (1850-52), T. Thomson, T. Anderson, C. B. Clarke, G. King (1890), D. Prain (1903), G. C. Odder (1910-1930), Janaki Amal (1952) (Anonymous 1990).

Emergences of Universities for Botanical Studies

In the ancient India there were many eminent centres for advance studies on language, religion and culture. These were situated at Takshasila, Pataliputra, and Benaras. Students of India and from foreign countries came to these centres for higher knowledge.

During the British Colonial period (1757-1947) Universities of European order functioned in different cities of India. First three Universities started functioning at Calcutta, Bombay, Madras in the year 1857.

The advanced studies on science started in the science college at Calcutta in the year 1814. This academic institute was opened during the tenure of the vice-chancellor of Sir Ashutosh Mukherjee. But higher studies on botany began at Calcutta in the year 1918. Many other Universities started teaching botany in different cities of India. Some of them were Benaras (1919), Aligarh (1920), Lucknow (1921), Allahabad (1922), Oamania (1924), Annamalai (1931), Madras (1933), Andhra (1945).

Botanical studies and research were started in Universities and research institutions in the colonial period, that is, in the preindependent era (Table - 3). After independent in the year 1947, there were many more universities in the country who are doing both teaching and research in botany. Progress on the botanical research is encourging.

Modern works on Botany

The modern Botanical research works can be divided in two broad classes cryptograms and phenorograms.

Important algal research had been done by the European scientist. They are the Portuguese, Dutch, and English. Indian Universities of Benaras, and Madras have done a good contribution in this field. Biswas (1932) of Botanical Garden, Shibpur, had recorded algal flora in different parts of India.

Many researches have been done on the fungus grown of Indian soil, by the European scientist in the early twentieth

century, Butlar (1918), and later Indian scientist Bose (1942). Workers of CRRI-Cuttack, and IARI New Delhi have made many important contribution on plant pathology and microbiology.

Bryophytes had a very long evolutionary period on earth. Its first appearance in the Devonian age and continues till to. In Indian soil modern studies have been done by Kashyap (1932) and later by Gangulee and chatterjee (1962), Gangulee (1972), Kumar (1983) are very interesting. There are many other important workers in this field.

Pteridophytes or the ferns have the wide distribution on Indian plains and hills. The works done by Mehara (1961), Bir (1972, 1983), on pteridophtes is worth mentioning. Work of Sahani (1923). Mahabale (1966) on gymnosperm is highly appreciated by the scientist.

In the field of paleobotany most of the earlier works were done by English botanist, Brongniart (1873), Royle and Arber (vide John and swami 1971) · Indian workers Sahani (1936). Mittre (1968) made important reports. The works of Sahani on the paleobotany was awarded the fellowship; of Royal Society England. Similarly the embryological work of P. Maheswary was internationally reputed, who was of recipient of F.R.S. England.

In the field of cytogenetics and crop improvement significant works have been done by IARI. Specially Mukherjee (1953), Jain (1972), Paul (1982), Swaminathan (1984) and their associates have done works on different crops and horticultural species of fruits plants. The chromosome analysis of Indian monocots have been completed by Sharma and Sharma (1959), sharma (1972) and many of his associates. The works on crop botany are applied oriented. It accomplishes to grow more food, fodder and fibre. This modern contribution have achieved successful to meet, the enormous demand of food for the population of our country.

Conclusion

The botanical studies had given enough opportunities for the human survival in the past and at present. The most important of them was the traditional system of medicine in India that is Ayurveda, as deyeloped by the Hindus. On the otherhand the Perso-islamic practices of medicine known as yunani was of its highest development during the period of muslim rulers of both Pathan and Moghul.

The drugs used by these people were from the common plants grown around. Thus the medicines were not very costly. People in the past years had met these practitioners for their treatment. It was cheap in those days for the poor Indian people. Therefore it can be recommended till today for further improvement and maintenance of health of the people.

In this respect it would not be out of place to mention the system of Homeopathy treatment. This system was introduced in India from outside. The treatment of homeopathy is done by the drugs obtained from different plants available all over the country. The medicine is cheap. It gives a shrap good result in many diseases. Therefore it can be improved tomorrow for the health care of the Indian people.

Thus it can be concluded that plant kingdom in general is still a great source of materials which can supply food, fodder, fuel and drugs for the mankind in the coming years. The History of Botany is still a source of inspiration to the academic people for future study and research.

Table – 1

The names of plants mentioned in the epic Ramayana, Mahabharata and Charak Sanghita

Common Name	Latin Name	Comments
Ramayana		
Arjuna	Terminalia arjuna	Medicinal plant
Bilva	Aegle marmelos	Medicinal plant
Kadamba	Anthocephalus cadamba	Flowering tree
Kimsuka	Butea monosperma	—do—
Tala	Borassus flabellifer	Edible fruit
Amra	Mangifera indica	—do—
Lodhra	Symplocos race mosa	Flowetigg tree
Amlaka	Ernblica officinalis	Fruits—Vitamin C
Shala	Shorea robusta	Woody tree
Ikshu	Sacharum officinarum	Fruit Juice—sugary
Mahabharata		
Bakula	Minusops elengi	Flowering tree
Karabira	Nerium indicum	Flowering tree
Kimsuka	Butea monosperma	Flowering tree
Haritaki	Terminalia chebula	Medicinal plant
Parijata	Nyctanthes arbor—tritis	Plants flowering

Common Name	Latin Name	Comments
Shala	shorea robusta	Inportant woody plant
Sapta Chada	Alstonea scholaris	Religious plant
Chanpaca	Michelia champac	Flower — fragrant
Arka	Calotropis gigentia	Flower used in devine worship.
Chandana	Santalum album	—do—
Charak Sanghita		
Bharadvaji	Abroma augusta	Uterine disease
Apamarga	Achyranthes aspera	Bronchial infection
Vasa	Adhatoda vasica	Pulmonary disease
Salmali	Bonbax ceiba	Stirnul ant
Durva	Cynodon dactylon	Bleeding wounds
Samanga	Mimosa pudica	Piles
Utpala	Nymphaea stellata	Skin disease
Pippali	Piper longum	Digestive
Raktachandan	Pterocarpus santalinus	Female disease
Erada	Ricinus communis	Purgative

Table – 2

Activities of Portuguese in India on plants Science & History (1498-1580)

Plant Species	Family	Comments	
Plants introduced in India			
Nicotiafla tabacum	Solanaceae	Tobacco plant used for its alkaloid— Nicotine.	
Aflaflasa sativa	Bromil iaceae	Its fruit is sweet and juicy.	
Caricza papya	caricaceae	After 1580 it was cultivated all over India.	
Anacardium oxidentails	Anacardiaceae	It gives edible nuts.	
Mirabilis jalapa	Nyctagen aceae	'Sandhya Malatl"— a comnvn flower in Bengal.	
Capsicurli annuarri	Solanaceae	Very coirmon in India — Called "Lanka".	
Psidium guyava	Myrtaceae	— "Peara" a common fruit of India.	
Soma orient ale	Tomas Pires	1515	Indian Ports & people Published — 1944.
Mannual of Graxmner and volabulary	Francis Xaviers	—	Indian language.
Christan epic	Thomas Stephens	—	European epics.
On Indian Society and culture	Durate Burpose	1518	Book on Indian Society

Subject/Book	Author	Year	Comments
Historia da discobrimento en Conguista da India Pels Pergugieres	Ferano Lopes de Castanhide		Book on Portuguese history.
Collaguios des Simples e Drogoes	Garci da orto	1563	Drugs of plants in Western Coast of India
Grammer of Bengali	Augustinian Mahoel da Asampco	1743	A Bengali Gramirer

Table – 3

Name of the organizations where plant Science was considered either for teaching or research

No.	Institutes	Year	Comments
1.	Asiatic Society of Bengal	1784	Resarch on Science and Culture.
2	Geological Society	1807	Research.
3	indian Museum	1814	– do –
4	Serampur college	1818	– Teaching.
5	Agri. Horticultural Society	1820	Research.
6	Sanskrit college	1821	Teaching
7	Medical College	1835	Teaching & Research.
8	University – Calcutta Bombay & Madras	1857	Teaching & Research.
9.	Indian Association for the cultivation of Science	1876	– do –
10.	Indian School of Forestry	1878	– do –
11.	Indian Agricultural Research station – Pusa Bihar	1905	–do–
12.	Indian Science congress	1914	– Research.
13.	Bose Institute	1917	–do–

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History of Physiology in the Nineteenth Century India

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Introduction

Physiology is one of the earliest subjects in the human civilization.

The knowledge of physiology and medicine in India is very old. Its earliest concepts are found in the **Vedas,** specially in the **Atharvaveda,** which possibly dates as far back as the second millennium B. C.[1]

Classical Indian concepts in physiology, anatomy are found in **Ayurveda — 'knowledge of long life'.** The medical literature authored by Susruta and Charaka are well known. Nowadays, it is almost unbelievable that the ancient Indian medical experts could transplant organs, like ear, nose, etc., which is now called plastic surgery[2]. The medical science that originated in ancient India spread widely, gave impetus to other parts of the world, like Middle East, Greece etc.

Unfortunately, India had lost her glorious past. During medieval period, there was a great stagnation of scientific knowledge. According to some, the cause might be due to political disturbance, foreign invasion, religious orthodoxy, etc.

In the midst of such a dark and dismal phase in India, the European countries made a remarkable progress in scientific field. As a consequence, the early A.D. Galen-ian concept in physiology and anatomy was mostly replaced by the discoveries of Vesalius, William Harvey and other scientists.

While the adventurous Europeans started pouring into India as traders, merchants, religious preachers, they never failed to bring with them the western science along with the Bible. For

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their own interest the British rulers engaged a few scientists. Sir Rennell, father of Indian Geography surveyed very precisely the rivers and roads of the then Bengal and published the famous *Bengal Atlas*. Explorations of geological and other natural resources were became essential to East India company for the economic value. Almost for the same reason, at the dawn of eighteenth century, Dinwiddie, who taught botany at Fort William, had made certain galvanic experiments.[3]

So far physiology and medical sciences, are concerned it is noted that the Indian elites were attracted even from seventeenth century with the marvellous curative treatments by the European surgeons. For instance, East India Company surgeon Gabriel Boughton cured the beloved daughter of Moghal emperor Shah Jahan. Almost in same manner, in the early part of eighteenth century, William Hamilton, a surgeon on the establishment at Fort William attended the diseased emperor Farooque Shah and restored him to health[4]. All these incidents put the western medical science in the dominant position than the traditional Indian methods of treatment i.e. Kaviraji, Unaṇi or other types.

The traditional education system was tols, madrasas where science was almost neglected. The Indians became medical practitioners or Baidyas by their birth right, not by qualifying themselves. In such a unorganised society the British rulers took charge of the country. At the beginning they were not interested to spread proper education for the natives. The Europeans for their own interest established the Asiatic Society for enquiring into the arts, history, sciences and litarature of Asia. The Governor General, Warren Hastings, was its chief patron and Sir William Jones was chosen as its president. The institution thus founded proved to be the fountain head of all literary and scientific activities in India and the mother of all learned organisations of the country. Every branch of scientific institutions in India owe its genesis to the Asiatic Society, which had made valuable and significant contributions in every field of knowledge. Surprisingly, at the begining the door of the Society was opened only to Europeans.[5]

Needless to mention, the Asiatic Society influenced much the elites of Indian citizen who became aware of scientific methodology and admirer of western and modern scientific approach.

Thus by, local Rajas, Zaminders and urban people gradually became more and more followers of the Europeans and also admirers of western system of education and tried to introduce western education establish and medical training centres etc. The great social reformer, Rammohan Roy was in favour of western education. He wrote a long letter to Lord Amherst, advocating the introduction of western pattern of education including science subjects like anatomy, physiology etc. in India.[6]

Nineteenth Century Education and Physiological Science

From the early years of nineteenth century, the establishment of Hindoo School in 1817, Calcutta Book Society (1817), school for Native Doctors (1822), Medical College in Calcutta and Madras (1835), Universities like Calcutta, Madras and Bombay (1857), the Indian Association for the Cultivation of Science (1876), were all the landmarks in the march of science in India.

Under the dynamic influence of Henry L.V. Derozio the erstwhile "young Bengal group" formed the 'Society for the Aquisition of General Knowledge', in short SAGK illustrious luminaries like Iswarchandra Vidyasagar, Debendranath Tagore, David Hare and scores of youth of Hindoo College enrolled themselves as the members of the organisation. The society existed from the 1838 to 1843 and regularly held a monthly meeting on the second Wednesday of each month.

The organisers published a number of selected discourses of which, at least three were found on physiological topic. Their titles were : 'Anatomy of Eye', 'On the anatomy of Ear' and 'On the physiology of Digestion'. These were read and discussed by Saut Kauri Dutta and Prasanna Coomer Mitra (student of Medical College)[7].

In the mean time, Felix Carey, son of William Carey of Serampore, wrote a book, entitled 'Vidyaharavulli' – a Bengali Encyclopedia on physiology and anatomy. It was the first of its kind and published in 1820.[8] Before the establishment of Medical College, to satisfy the demand of hospitals and army, a native Medical school was opened in 1822. Medical classes were started at the Sanskrit College and Calcutta Madrasa. Similar experiments were conducted in Bombay and Madras as well.

But the lifespan of Native Medical school and the medical course at Sanskrit College and Madrasa were short lived. In 1835, when a full-fledged Medical College was established, the previous systems were abolished. Calcutta Medical College was the place, where the first dissection of human corpse took place on January 10, 1836 — an event against the century old orthodoxy and superstitions of the country. It was a red letter day in the history of medical science in India. Calcutta Fort William commemorated the event by booming 21-gun salute.

For the uplift of medical education Dwarakanath Taogre offered annual prize of Rs. 1000, and Muttylal Seal donated a large piece of land (present Medical College Campus). In 1845 four Indian medicos were sent to England for higher studies. They were Bholanath Basu, Surya Kumar Chakraborti, Gopal Chandra Seal and Dwarakanath Basu.[9]

The establishment of colleges, universities and other learned societies in the country yield a scientific temper among the educated people. Though the British rulers did not encourage scientific research, most of the science societies, associations and institutions were the outcome of private initiative and could not have been sustained without public support.

Meanwhile the Universities at Calcutta, Bombay and Madras and Medical colleges produced scholars for the country. Mahendralal Sircar, a scholar of Calcutta Medical College by his own endeavour science started the first research centre — Indian Association for the Cultivation of Science.

In the nineteenth century there were a few journals for medical research publications. Some of them were : Ind. Med. Gazettee (1866), Calcutta Jr. of Medicine (1868), Madras Qrt. Med. Jr. (1839), Madras Monthly Jr. of Med. Sc., (1870), Ind. Med. Record (1890) — where a good number of research papers in physiology could be observed. Besides this, individual endeavours produced some significant research publications, mostly by Europeans. Mention may be made of Ronald Martin's works on 'Note on the Medical Topography on Calcutta and its Suburbs' (1837). Charles Macnamara, who came to Calcutta as eye-surgeon, but became interested to search on cholera. He wrote a valuable book on 'Asiatic cholera' (1870). A good number of European scientists made research on tropical diseases, some of the them became famous for their contribution. As Robert Koch, who came over to India in 1883 to confirm his discovery

on cholera bacilli. Leonard Rogers spent almost his whole life in the research of tropical diseases ('Roger' Canula') He was the key person in making School of Tropical Medicine, Calcutta. In this context, the most significant name should be of Ronald Ross, for his break-through research on Malarial parasites. Owing to this, he was awarded the Nobel prize in physiology and Medicine (1902).

The significant research works of Europeans in India created impetus upon young Indian scientists like Acharya P. C. Ray, J. C. Bose, Ashutosh Mookerjee in the later part of nineteenth century resulting the formation of their respective schools and subsequently they became famous during twentieth century. It is noteworthy that some of the experiments performed by Sir J. C. Bose were on physiology — both plant and animal.

In the nineteenth century the subject physiology became popular and that could be ascertained by the fact that a good number of articles on physiological subjects were published in various periodicals of that time. Some of the periodicals are Sambad Pravakar, Sulav Samachar, Tattwabodhini, Arya Darsan, Bamabodhini, Bandhav, Bangadarshan and others. The science articles written by Akshoy Kr. Dutta, Rajendralal Mitra, Bankim Chandra Ramendra Sundar Trevedi were very significant in popularisation of science. The 'Bijnan Rahasya' by Bankim Chandra, contains two articles on physiology. In 1875, the Calcutta School Book Society published a Catalogue of Bengali literature with 333 books on science and technology of which there were 99 titles physiology and anatomy.[10]

In the last quarter of the nineteenth century there was a trend of publishing books and monographs in vernacular which dealt with physiology. Some such Bengali publications were :

1. Phijology ba Sarir Bidhantattwa (1882) by Mahendranath Ghosh.
2. Nara Sarir Bidhan (1883) by Ashutosh Mitra.
3. Narideha Tattva (1884) by Birendranath Pal.
4. Rakta Sanchalan (1885) by Dwarakanth Gupta.
5. Samkhipta Sarirtattva (1891) by Radha Gobinda Kar.
6. Sarir Byabacched O Sarirtattva Sar (1894) by Jogendranath Mitra.

Conclusion

Though in isolated and discrete way the subject of physiology was to discussed, articles published in different journals during nineteenth century but almost no infrastructure for research work in the country was available at that time.

However, almost at the beginning of twentieth century, Prof. Subodh Chandra Mahalanobis a far sighted physiologist, introduced physiology as a basic subject in Presidency college in 1902. Moreover, some scientific institutions, laboratories were gradually grown up in the twentieth century. Henceforth, modern physiological knowledge and research started methodically rendering service to mankind.

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Difficulties and Procedures in the Development of Scientific Awareness and Consciousness

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Scientific awareness is an attitude of life which helps us to understand things and phenomenon in their true perspective. Scientific awareness may lead to scientific consciousness if properly cultivated. If we have mentally equipped ourselves with the armour of causality, which is the phenomenon of cause and effect, then we can say we are scientifically aware to judge a thing properly. This being so, it leads us to the development of true scientific consciousness if we are free from superstitions and obscurantist ideas.

Out of the work of the great men of the seventeenth century, a new outlook on the world was developed and it was this outlook, not specific arguments, which brought about an apparent decay of the belief in portents, witchcraft, demoniacal possession and superstitious ideas. There were three ingredients in the scientific outlook of the eighteenth century that were specially important.

Firstly, statements of facts should be based on observation and not on unsupported authority.

Secondly, the inanimate world is a self acting, self-perpetuating system, in which all changes conform to natural laws. And thirdly, the earth is not the centre of the universe and probably Man is not its purpose (if any). Of course, it must be said that purpose is a concept which is scientifically not tenable.

The above mentioned statements make up what is called the 'mechanistic outlook', which clergymen denounced.

To modern educated people, it seems obvious, that matters of fact are to be ascertained by observation and not by consulting

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ancient authorities. But this is an entirely modern conception which hardly existed before the seventeenth century.

Statement & observation

Aristotle, one of the greatest of philosophers maintained that women have fewer teeth than men. Although he was twice married it never occurred to Aristotle to verify this statement by examining his wives mouths. He also said that children will be healthier if conceived when the wind is blowing from the north. He stated that a man bitten by a mad dog will not go mad but any other animal will. Please do not laugh at Aristotle when he says that the bite of the shrew mouse is dangerous to horses, especially if the mouse is pregnant and that elephants suffering from insomnia can be cured by rubbing their shoulders with salt, olive oil and warm water and so on and so forth.

Nevertheless, classical dons, who had perhaps never observed any animal except the cat and the dog continued to praise Aristotle for his fidelity to observation. Pliny, a great historian of earlier times had said that ostriches eat nails. People believed it. It never occured to them how the poor ostriches found the nails in the bush.

Science and Reason

Science should not be defined as any particular subject. It is rather a method which helps us to analyse a situation or a phenomenon properly. There is nothing called 'a priori' in science. Science does not accept anything as pre-ordained.

The problem arises when a well-educated person or a hard-boiled scientist fails to act as a rational person, as one free from superstition. This was evident to us particularly during the total solar eclipse phenomenon of 1980 and 1995, which was visible from quite a number of states of India. In 1980, on 16th February, nearly 500 scientists had assembled at Osmania observatory near Hyderabad to observe the total solar eclipse; there were quite a number of foreign scientists amongst them.

As soon as the partial eclipse started at 2.15 p.m. (totality occured at 3.15 p.m.), two young journalists who had come from Kerala started distributing coffee and biscuits among the scientists. The foreign scientists accepted them gladly but among

the Indian scientists, barring a few, the others refused to accept them. Why was it because of the superstitious ideas held from their childhood days that if you take food or drink during solar or lunar eclipse period, then it might cause physical harm to you.

Superstition dies hard

Were not the Indian scientists at Osmania observatory aware about what causes a solar eclipse ? Of course, they were. Did they not know that during eclipse no food or drink is affected by bacterial infection. Many of them did. Still why did they behave in such an unscientific manner? It was because they lacked the proper scientific consciousness and reasoning to act in a decisive manner. It was all because of superstition.

In 1980, the medical adviser to the government of India made a public announcement that during solar eclipse, pregnant women should not come out of their dwellings. If they do, the human embryo in their wombs will be affected in an adverse manner by mysterious radiation from the sun. The honourable medical adviser was absolutely ignorant about the fact that no mysterious radiation come out from the sun during eclipse. The physical nature of radiation from the sun remains exactly the same during eclipse as it was before the phenomenon. All the streets of major metropolitan centres of India on 16th February 1980 were almost deserted because of such irresponsible statements. People were simply afraid to come out of their houses.

During 24th November 1995 total solar eclipse, people had come out in millions at least in West Bengal, to observe the phenomenon. It was all because of the year-long educational campaign conducted throughout the state by Paschimbanga Vigyan Mancha, the largest peoples' science organisation in West Bengal and other like-minded bodies.

'Ganesh is drinking milk', was another fraud which was adopted by the religious fundamentalist groups in our country in 1994. Some highly educated persons in the society had even believed this and came out in its support. But the entire fraud behind this myth was exploded in 24 hours by the combined efforts of various science organisations and mass media. The phenomenon of surface tension, capillary action and gravity were taken recourse to by interested bodies to perform this fraud.

Astrology versus Astronomy

A few years back, University Grants Commission of government of India had sent a request to all the universities of India to incorporate into their curriculum courses on Astrology and priesthood in the graduate and post-graduate level. It was a heartening news that majority of our universities had rejected the offer.

Astrology is entirely an anti-science affair. Pandit Kshitimohan Sen Shastri, the reknowned scholar and himself an erudite person on Astrology had categorically said that it is only after thoroughly learning about Astrology that I have come to know that it is absolutely false.

Right from the Vedic days till the period of Aryabhata, 5th century A.D., for nearly one thousand years, Vedanga Jyotish was cultivated on the basis of observation of planets (known till that date) and their position in relation to the stellar clusters or Rashichakras (twelve in number). This study was necessary for calculating the exact time for performance of various yagnas. It was never used for preparation of horoscopes and announcing beforehand about what is going to happen to a person in the future because of the occult power of planets and Rashis. Study of Jyotisha in the early period had a scientific component in it. It was only from the period of Varahamihira, which was roughly 10th century A.D. that Phalita Jyotisha, as we know it to-day started being practised. With it came all the anti-science falsehoods.

Every means of mass media to-day have become agents of Astrology. Thousands of 'Sani's temple' are adorning the street corners of Calcutta to-day which were not at all visible even twenty years ago from now. What are the reasons? Are the highly educated persons among whom are quite a number of noted scientists, have suddenly become superstitious abandoning all elements of scientific temper. It is a subject for an intensive social study.

Science and anti-science

One can practice religion in his own way, according to the rituals. But religion and religious blindness are entirely two different things. The latter leads us to superstition and bigotry.

The educated section of the society, if not free from superstition and religions blindness (the government included), poses the greatest difficulty in the development of scientific awareness. It is because the non-educated section look up to them for guidance. If they do not get that guidance, both intellectual and spiritual, progress of the society get stagnated.

Acharya Prafulla Chandra Ray, in his reknowned work, 'History of Hindu Chemistry' had made a prophetic statement. India was at the height of learning and erudition from 5th century B.C. to 5th century A.D. Thousands of students used to gather at our ancient universities of Tyaxsila, Nalanda, Vikramshila, Ballavi, Odontapuri and others from various countries of Asia for pursuits of knowledge at various branches of arts and sciences. Why then suddenly the downfall started ? According to P.C. Ray, it was because of two reasons. Firstly, Sankara's Mayavad, which brought about a tremendous damage to the growth of rational and scientific knowledge and thinking. Secondly, it was the separation between manual and intellectual workers.

Manual workers comprised the artisans and craftsmen of our society. They were our potters, carpenters, weavers, smiths and other technicians. Whenever they faced any problem, particularly in the production technique, they had no access to the then scientists and technologists for any advise or guidance. It was barred by the Brahmin sect of the society. Stagnation and decline naturally followed from both sides.

What is to be done ?

All the avenues for direct approach to the general mass for development of scientific awareness and consciousness have to be made use of. Audio-visual lectures, exhibitions, publication of books and leaflets, documentary films, science-based songs and dramas and cultural jathas covering hundreds of kilometres and coming across thousands of people where all the means mentioned earlier are made use of to achieve the desired end. These educational programme are to be pursued continuously against heaviest odds. Wherever it has been so, the result has been positive. Man's inner desire for positive and rational knowledge and thinking should never he underestimated. Proper

guidance and involvement, that is what is necessary. Peoples' science movement in West-Bengal and elsewhere are busy with that programme of action.